Animal Science 1997, **64**: 97-104
© 1997 British Society of Animal Science
1357-7298/97/57360097$20·00

Genetic resistance of different genotypes of sheep to natural infections with gastro-intestinal nematodes

Endang Romjali[1], V. S. Pandey[2]†, R. M. Gatenby[1,3], M. Doloksaribu[1], H. Sakul[3], A. Wilson[4] and A. Verhulst[2]

[1]*Research Institute for Animal Production, Sungai Putih PO Box 1, Galang, Deli Serdang 20585, North Sumatra, Indonesia*
[2]*Prince Leopold Institute of Tropical Medicine, Nationalestraat 155, B-2000 Antwerp, Belgium*
[3]*SR-CRSP, Department of Animal Science, University of California, Davis, CA 95616, USA*
[4]*Indonesia International Animal Science, Research and Development Foundation, (INI, ANSREDEF), PO Box 1093, Boo, Bogor 16010, Indonesia*

Abstract

During a 3-year period, from April 1991 to December 1993, in a flock with four lambing periods annually, faecal samples from lambs at weaning at the age of 3 months (no. = 1756), were examined for gastro-intestinal nematode eggs by the McMaster method. Faecal samples were also examined at the age of 9 (no. = 170), 12 (no. = 157), 15 (no. = 153) and 18 (no. = 85) months from the females only. From June to December 1993 packed cell volume (PCV) was also examined from lambs at weaning. Seven genotypes were used in this study.

The faecal egg counts were affected by genotype, birth season, type of birth and rearing, sex and age. First generation cross of Sumatra × Barbados Blackbelly had lowest eggs per g of faeces (EPG) followed by Sumatra, St Croix, Sumatra × St Croix F1 and F2 and Sumatra × Java Fat tail. Lambs born in February-March when rainfall was low had lower EPG ($P < 0.05$) than those born in May-June or August-September. The EPG of lambs born and reared singly were significantly lower ($P < 0.001$) than those born twin, triplet or quadruplet. Female lambs had lower EPG than male lambs ($P < 0.001$). The EPG of lambs at 3 months were higher than at 9, 12, 15 or 18 months ($P < 0.001$).

PCV was affected by genotype, sex, type of birth and rearing and season of birth. There was a positive correlation between PCV and weaning weight of lambs and a negative correlation between EPG and weaning weight. These results show that the crosses of St Croix and Barbados Blackbelly with local Sumatra sheep are at least as resistant or more resistant to gastro-intestinal nematodes than pure Sumatra breed and therefore these breeds can be used in cross breeding programmes to improve the body size of local Sumatra sheep.

Keywords: *Genetic resistance, Indonesia, nematoda, sheep.*

Introduction

The potential of sheep production under rubber plantations in the humid tropics of south-east Asia in general and in Sumatra in particular, is high (Devendra, 1991). One of the major constraints to sheep production in these areas is the infection with gastro-intestinal nematodes. Due to favourable climatic conditions, the risk of transmission of gastro-intestinal nematodes to grazing animals is present throughout the year (Ikeme *et al.*, 1987; Dorny *et al.*, 1994). Generally, the animals acquire infection early in life and suffer high production losses and mortality if left untreated (Handayani and Gatenby, 1988). Current control practices rely heavily upon the frequent use of anthelmintics which leads to development of anthelmintic resistance (Pandey and Sivaraj, 1994; Sivaraj and Pandey, 1994; Sivaraj *et al.*, 1994). Therefore, alternative control strategies are being considered, which reduce the reliance on

† Author for correspondence.

chemotherapy. One such strategy is the genetic improvement of the host resistance to nematodes (Gray, 1991; Pandey *et al.*, 1994).

Variations in resistance between breeds and within breeds have been reported and have recently been reviewed (Kassai and Sreter, 1992; Gray *et al.*, 1995). Nematode burden and its effect on pathological and production parameters is influenced by genetic as well as by environmental factors. The age, sex, climate, nutrition, grazing management, physiological conditions and immunity affect the susceptibility to nematode infections and consequently the parameters measured (Gruner, 1991; Wakelin, 1992). Therefore, for comparisons of different breeds/genotypes to be valid, it is important that such comparisons are made under similar conditions.

The local Sumatra sheep is a prolific breed but small in size. Therefore, other breeds have been introduced with a view to produce synthetic genotypes with larger body size and at the same time adapted to the humid tropics. The objective of the present work was to study the natural infections of various genotypes of sheep with gastro-intestinal nematodes, predominantly *Haemonchus contortus* in north Sumatra, Indonesia and to identify the factors affecting them. The factors considered were genotype, season, number of lambs born and number of lambs reared, age, sex and effect of worm burden and packed cell volume (PCV) on weaning weight of lambs.

Material and methods

Location and climate

The study was conducted at Sungai Putih in Galang District (3° 24' N, 98° 53' E, altitude 50 m) about 60 km south of Medan, north Sumatra, Indonesia. At the study site, *Haemonchus contortus* is the most important parasite. Some *Trichostrongylus colubriformis*, *Cooperia* spp. and *Oesophagostomum* spp. are also encountered (unpublished observations).

The climate of the area is hot and humid with little fluctuation in temperature during the year. Average minimum temperature is about 23°C, and average maximum temperature 32°C, with little seasonal variation. Annual rainfall totals about 1800 mm. The monthly rainfall recorded at Sungai Putih during the 3-year period of study is presented in Figure 1.

Animals

Sumatra, the local sheep breed in north Sumatra, formed the original base population. St Croix breed, also known as Virgin Island, originally from the Caribbean was introduced into the flock at Sungai

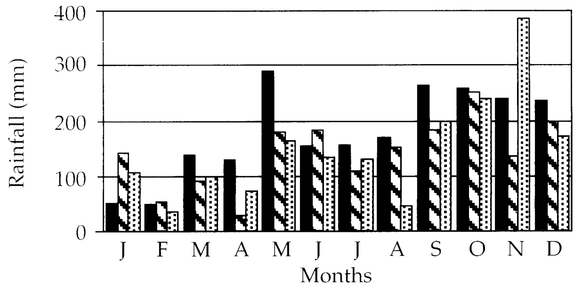

Figure 1 Monthly rainfall in 1991, 1992 and 1993 at Sungai Putih, the site of study. ■ 1991; ▧ 1992; ⬚ 1993.

Putih in 1986 from the United States. In 1991 Java Fat-tail sheep, known in Indonesia as Ekor Gemuk, were also introduced from east Java, and frozen semen of Barbados Blackbelly was imported from Barbados. Sumatra sheep and their crosses with Barbados Blackbelly, Java Fat-tail and St Croix were studied.

The seven genotypes included in the experiment were as follows: local Sumatra, St Croix or Virgin Island, Java Fat-tail, 0·5 Sumatra 0·5 St Croix F1 and F2, 0·5 Sumatra 0·5 Java Fat-tail F1, 0·5 Sumatra 0·5 Barbados Blackbelly F1.

The ewes were exposed to rams for 34-day periods, four times a year (January, April, July, October). Natural services were individually supervised following twice-daily detection of oestrus by vasectomized rams. Most lambs were born in June, September, December and March. They were weaned at 3 months of age which fell in September, December, March and June.

Grazing management and feeding

The sheep were housed in group pens in four large houses with raised slatted floors. Ewes and suckling lambs were grazed from 08.00 h to 16.00 h daily in rubber plantations. The vegetation under rubber trees was predominantly grass, *Ottochloa nodusa*, *Axonopus compressus* and *Paspalum conjugatum*. Ewes with single lambs were given concentrates for 2 weeks after lambing, and those with two or more lambs received concentrates until lambs were weaned at exactly 3 months of age. The concentrate contained molasses, cassava meal, rice bran, palm kernel cake, urea and minerals and each ewe received 300 g daily. At weaning all the animals were given anthelmintic and kept inside the pens up to the age of 6 months. Females were again allowed to graze from the age of 6 months whereas males remained permanently indoors and were offered the fodder cut and carried from clean pastures. As a routine, all grazing sheep were given anthelmintic every 3 months, then the next day were moved to a

Table 1 *Number of experimental lambs by genotype and birth group at 3 months of age*

Year	Birth group†	Genotype							Total
		Sumatra	St Croix	Java Fat-tail	Sumatra × St Croix F1	Sumatra × Java Fat-Tail F1	Sumatra × Barbados Blackbelly F1	Sumatra × St Croix F2	
91	1	82	13	2				28	125
91	2	41	18	4				33	96
91	3	23	10	1				33	67
91	4	3	19	21				36	79
92	1	91	23	9	108	120	67	27	445
92	2	24	15	19	27	35		47	167
92	3	76	25	15	69	69		28	282
92	4	29	12	1				24	66
93	1	45	16					66	127
93	2	67	1					77	155
93	3	62	12					73	147
Total		543	174	72	204	224	67	472	1756

† Birth group: 1 = born in February-March; 2 = born in May-June; 3 = born in August-September; 4 = born in November-December.

new grazing area that had been spelled (ungrazed) for 3 months. All the genotypes were managed under similar conditions.

Faecal sampling and examination
Faecal samples were taken during a 3-year period from April 1991 to December 1993, every 3 months. Samples were examined from lambs of both sexes at weaning at 3 months (no. = 1756), and from females only, at 9 (no. = 170), 12 (no. = 157), 15 (no. = 153) and 18 (no. = 85) months of age.

Faecal samples were collected from the rectum and examined by the McMaster method with the sensitivity of each egg counted representing 30 eggs. The counts were expressed as eggs per g of faeces (EPG).

Packed cell volume (PCV)
Starting in June 1993 blood samples were taken at the same time as faecal samples. Blood was taken from the jugular vein using vacutainers containing ethylene diamine tetra-acetic acid. Percentage PCV was estimated using the micro haematocrit method.

Body weight
Animals were weighed at weaning, at the same time as faecal collection, the sensitivity of the weighing machine being 0·1 kg.

Statistical methods and analysis
The numbers of 3 month-old lambs examined in this study are presented in Table 1. Data were analysed using least-squares procedures to account for unequal subgroup sizes (Statistical Analysis Systems Institute, 1987). The analyses of EPG data were completed after a logarithmic transformation by $\log_{10}(EPG+1)$. The results presented show least-square means of the transformed data, and also geometric means obtained by exponential reconversion of the transformed data.

Data were analysed for the following main factors: (1) effect of genotype on EPG; (2) effect of season on EPG; (3) effect of type of birth (number of lambs born) and rearing (number of lambs reared) on EPG; (4) effect of genotype, sex, season and type of birth and rearing on PCV; (5) effect of EPG and PCV on weaning weight; (6) effect of age on EPG.

Birth groups were divided according to year and season into eleven 3-month intervals covering the duration of the experiment (1991 to 1993).

There were four birth and rearing groups: 11 (born single, reared single); 21 (born twin, reared single); 22 (born twin, reared twin); 32 (born triplet, reared twin). All lambs born as triplets or quadruplets were included in the 32 category.

Results

Effect of genotype on faecal egg count
Egg count data from 426 contemporary lambs born in February-March 1992 which included six genotypes, were analysed using a model which included breed, sire within lamb breed, sex, type of birth and rearing. The lowest EPG were found in Sumatra × Barbados Blackbelly and the highest in Sumatra × Java Fat-tail lambs (Table 2). Pure St Croix and Sumatra lambs had similar egg counts.

Table 2 *Faecal egg counts (eggs per g of faeces) of lambs of six genotypes at the age of 3 months*

	No.	LS mean	s.e.	Significance	Geometric mean
Lamb genotype					
Sumatra × Barbados Blackbelly	65	$2{\cdot}48^{a}$	0·15		302
Sumatra	90	$3{\cdot}01^{ab}$	0·13		1023
St Croix	22	$3{\cdot}06^{ab}$	0·34		1148
Sumatra × St Croix F2	26	$3{\cdot}29^{ab}$	0·30	*	1950
Sumatra × St Croix F1	106	$3{\cdot}47^{b}$	0·16		2951
Sumatra × Java Fat-tail	117	$3{\cdot}51^{b}$	0·20		3236
Birth group (born in)					
92-1 (15 Feb-20 March 1992)	313	$3{\cdot}28^{a}$	0·08		1905
92-2 (15 May-20 June 1992)	81	$3{\cdot}28^{b}$	0·13	*	6310
92-3 (15 Aug-20 Sept 1992)	212	$3{\cdot}78^{b}$	0·09		6026
Type of birth and rearing					
11 (born single reared single)	558	$3{\cdot}18^{a}$	0·07		1514
21 (born twin reared single)	78	$3{\cdot}47^{b}$	0·12	**	2951
22 (born twin reared twin)	370	$3{\cdot}35^{b}$	0·08		2238
32 (born triplet, quadruplet reared twin)	118	$3{\cdot}44^{b}$	0·01		2754
Sex					
Female	584	$3{\cdot}26^{a}$	0·07	**	1820
Male	540	$3{\cdot}45^{b}$	0·07		2818

[a,b] Means not having a common superscript within a column are significantly different.

The ranking for EPG was Sumatra × Java Fat-tail > Sumatra × St Croix F1 > Sumatra × St Croix F2 > St Croix > Sumatra > Sumatra × Barbados Blackbelly. Faecal egg counts of Sumatra × Barbados Blackbelly were significantly lower than Sumatra × Java Fat-tail and Sumatra × St Croix ($P < 0{\cdot}05$). There were no significant differences between EPGs of other five genotypes studied ($P > 0{\cdot}05$).

Effect of birth group (birth season) on faecal egg count

As there were no significant differences between the EPG of Sumatra, Sumatra × St Croix F1 and Sumatra × Java Fat-tail the data of these three genotypes in a given period were pooled together to analyse the effect of birth season. Season of birth had a significant effect on faecal egg count of lambs at 3 months of age (Table 2). Faecal egg counts of birth group 92-1 (lambs born 15 February 1992 to 20 March 1992) were lower ($P < 0{\cdot}05$) than those of groups 92-2 (lambs born 15 May 1992 to 20 June 1992) and 92-3 (lambs born 15 August 1992 to 20 September 1992). The EPGs of lambs in groups 92-2 and 92-3 were similar.

Effect of type of birth and rearing on faecal egg count

Analysis of the data of 1124 lambs from all sampling periods under study showed that the type of birth and rearing had a significant effect on faecal egg count at 3 months of age ($P < 0{\cdot}001$). Table 2 shows that the mean EPG for single lambs was lower than that for twins reared as singles, twins reared as twins and triplets and quadruplets reared as twins ($P < 0{\cdot}001$).

Effect of sex on faecal egg count

Faecal egg counts were affected by sex, males having higher EPG than females ($P < 0{\cdot}001$; Table 2).

Effect of lamb genotype, birth group, sex and type of birth and rearing on PCV at 3 months of age

The PCV of individual lambs of three genotypes examined (no. = 420) ranged from 13·1 to 38·5%. PCV

Table 3 *Packed cell volume (%) of lambs according to genotype, sex, type of birth and rearing and birth group at the age of 3 months*

	No.	LS mean	s.e.
Lamb genotype			
St Croix	39	$24{\cdot}3^{a}$	0·7
Sumatra × St Croix F2	212	$27{\cdot}7^{b}$	0·5
Sumatra	168	$27{\cdot}6^{b}$	0·5
Sex			
Female	218	$27{\cdot}2^{a}$	0·4
Male	202	$25{\cdot}8^{b}$	0·4
Type of birth and rearing (tbr)			
11 (born single reared single)	211	$28{\cdot}0^{a}$	0·3
21 (born twin reared single)	23	$27{\cdot}2^{ab}$	0·2
22 (born twin reared twin)	135	$25{\cdot}3^{b}$	0·4
32 (born triplet, quadruplet, reared twin)	51	$25{\cdot}5^{b}$	0·6
Birth group			
93-1 (15 Feb-20 March 1993)	122	$24{\cdot}9^{a}$	0·5
93-2 (15 May-20 June 1993)	154	$28{\cdot}0^{b}$	0·5
93-3 (15 Aug-20 Sept 1993)	144	$26{\cdot}7^{b}$	0·4

[a,b] Means not having a common superscript within a column are significantly different ($P < 0{\cdot}001$).

Table 4 *Least-square means for weaning weight (WWT), eggs per g (EPG) and packed cell volume (PCV) of lambs of five genotypes at the age of 3 months*

Genotype	No.	WWT (kg)		EPG			PCV		
		Mean	s.e.	Mean	s.e.	Geometric mean	No.	Mean	s.e.
Sumatra × Java Fat-tail	221	8·7[a]	0·3	3·68[a]	0·11	4800			
St Croix	154	10·6[b]	0·3	3·18[b]	0·13	1500	39	24·4[a]	0·7
Sumatra × St Croix F1	191	9·1[a]	0·4	3·79[a]	0·15	6200			
Sumatra × St Croix F2	454	11·1[b]	0·2	3·40[ab]	0·09	2500	212	27·7[b]	0·5
Sumatra	551	8·2[a]	0·2	3·46[ab]	0·10	2900	168	27·6[b]	0·5

[a,b] Means not having a common superscript within a column are significantly different ($P < 0{\cdot}05$).

Table 5 *Regression coefficients of eggs per g (EPG) and packed cell volume (PCV) on weaning weight of genotype*

Genotype	No.	EPG		No.	PCV	
		b	s.e.		*b*	s.e.
Sumatra × Java Fat-tail	211	–0·553	0·182			
St Croix	154	–0·467	0·186	39	0·237	0·078
Sumatra × St Croix F1	191	–0·209	0·171			
Sumatra × St Croix F2	454	–0·281	0·127	212	0·230	0·040
Sumatra	511	–0·235	0·109	168	0·213	0·044

was affected by lamb genotype, sex and type of birth and rearing and birth group (Table 3). The PCV of St Croix lambs was lower than those of Sumatra × St Croix and Sumatra ($P < 0{\cdot}001$) .

Average PCV of single lambs was significantly higher than for those born and reared as twins and those born as triplets and quadruplets ($P < 0{\cdot}001$). However there was no significant difference between single lambs and twins reared as singles.

Average PCV of birth group 93-1 was significantly lower ($P < 0{\cdot}001$) than for those of birth groups 93-2 and 93-3 which were similar. Average PCV of female lambs was significantly higher than that of males ($P < 0{\cdot}001$).

Effect of faecal egg count and PCV on weaning weight

Least-square means for weaning weight, EPG and PCV at weaning are presented in Table 4. The weaning weights of Sumatra, Sumatra × Java Fat-tail and Sumatra × St Croix F1 lambs were significantly lower than those of St Croix and Sumatra × St Croix F2 ($P < 0{\cdot}05$). Sumatra × Java Fat-tail and Sumatra × St Croix F1 had the highest and St Croix had the lowest faecal egg counts ($P < 0{\cdot}05$). Of the three genotypes examined, the PCV of Sumatra and Sumatra × St Croix F2 were higher than those of St Croix ($P < 0{\cdot}05$).

Linear regression coefficients of weaning weight on EPG and PCV are presented in Table 5. All regressions of EPG were negative, indicating that weaning weight was expected to decrease with increasing EPG. All linear regression coefficients of weaning weight on PCV were positive, indicating that weaning weight was expected to increase with increasing PCV.

Effect of age on faecal egg count of females

Faecal egg counts of females examined at 3, 9, 12, 15 and 18 months of age were affected by age group ($P < 0{\cdot}01$), birth group ($P < 0{\cdot}001$), sire ($P < 0{\cdot}01$) and type of birth and rearing ($P < 0{\cdot}05$), but were not affected by lamb genotype and lamb genotype × birth group.

Faecal egg counts of the five age groups are presented in Table 6. The average of EPG at 3 months was higher than at all later ages of 9, 12, 15, 18 months. The rankings were 15 < 12 < 9 < 18 < 3 month.

Discussion

Faecal egg count in mixed natural infection or single species experimental infection is considered to be a practical, valuable and most commonly used criterion of genetic resistance of sheep to

Table 6 *Faecal egg counts (eggs per g faeces) of females of different age groups*

Age groups (months)	No.	LS mean	s.e.	Geometric mean
3	622	3·30[a]	0·10	1995
9	170	2·18[b]	0·12	151
12	157	2·14[b]	0·12	138
15	153	2·09[b]	0·12	123
18	85	2·28[b]	0·15	191

[a,b] Means not having a common superscript within a column are significantly different ($P < 0{\cdot}001$).

trichostrongyles (Gray, 1991; Kassai and Sreter, 1992; Sreter *et al.*, 1994). Also it has been shown that the faecal egg count measured in weaned lambs is a good indicator of resistance levels for most of the adult life of the animal (Woolaston, 1990; Gray, 1991). There is evidence to suggest that animals which are resistant to one species of trichostrongyles are also resistant to a range of related nematodes (Windon, 1990; Woolaston *et al.*, 1990; Gray *et al.*, 1992; Sreter *et al.*, 1994).

Comparison of EPG from contemporary lambs of six genotypes, all born in February-March 1992 (Table 2) showed that F1 cross of Sumatra × Barbados Blackbelly had lowest egg counts followed by Sumatra, St Croix, Sumatra × St Croix F1, F2 and Sumatra × Java Fat-tail. However when the EPG data of weaned lambs for 11 lambing periods during 3 years, 1991, 1992, 1993, were analysed (Table 4) the lowest egg counts were found in St Croix followed by Sumatra × St Croix F2, Sumatra, Sumatra × Java Fat-tail. These differences between two analyses may have been due to different sample sizes of various genotypes in two analyses. However it is clear that crosses of Java Fat-tail have the highest egg counts; the local Sumatra genotype and its crosses with Barbados Blackbelly and St Croix have lower egg counts depending upon the period analysed. St Croix has been shown to be more resistant to *H. contortus* infection than Barbados Blackbelly, Florida Native or crosses of European breeds (Courtney *et al.*, 1985). In a later study Zajac *et al.* (1990) confirmed the high resistance of St Croix as compared with Florida Native and Dorset × Rambouillet. Although the present study is not conclusive, it suggests that imported breeds, Barbados Blackbelly and St Croix may be used in crossbreeding with local Sumatra breed to increase the body size of the latter.

The lambs born from February to March 1992 (birth group 92-1) had lower faecal egg counts than those born from May to June 1992 (birth group 92-2) and from August to September 1992 (birth group 92-3). These results are consistent with climate particularly the rainfall. The total rainfall of the period when the lambs of 92-1 group were grazing with their dams (February, March, April) was lower than groups 92-2 (May, June, July) and 92-3 (August, September, October) (Figure 1). The lower rainfall may have led to low infection pressure by infective larvae on pasture which was reflected in lower EPG at weaning.

Type of birth and rearing affected egg counts. Single lambs had lower faecal egg counts than twins or triplets. The likely reason for this may be that single lambs have better body condition, high birth and rearing weights, and also no competition from siblings for milk from their dams.

The average faecal egg count of females (EPG 1820) was lower than that of males (EPG 2818). The PCV of females (27·2) was higher than that of males (25·8). Windon and Dineen (1981) found greater immune responses in female than in male lambs vaccinated with irradiated larvae of *Trichostrongylus colubriformis* before puberty. Egg counts of ewe lambs were significantly lower than those from wethers (Yazwinski *et al.*, 1981). Courtney *et al.* (1985), however, found that natural resistance of ewe lambs to *H. contortus* was higher than of ram lambs but only after puberty.

The lambs compared in the present study were aged 3 months. The average age at puberty in Sumatra sheep and crosses with St Croix is 7·5 months (unpublished observations). Perhaps the natural resistance of female lambs had already developed because the lambs were exposed to natural infection from the age of 2 weeks.

This study showed a significant effect of age on faecal egg counts of female sheep. Faecal egg counts at 3 months of age were significantly higher than at 9, 12, 15 and 18 months (Table 6). High faecal egg counts in young lambs have also been reported by Dorny *et al.* (1994). They found that faecal egg counts of sheep in Malaysia increased rapidly to reach means of around 3000 EPG at the age of 2 to 4 months. Douch and Morum (1993) reported that faecal egg counts of mixed strongyle infection at 8 weeks after grazing commenced, were significantly higher in 4-month-old (EPG 1933) than in 16- (EPG 667) or 28- (EPG 383) month-old Romney sheep.

The two genotypes, St Croix and Sumatra × St Croix F2, which produced the heaviest lambs at weaning (10·6 and 11·1 kg respectively) also had the lowest EPG (1500 and 2500 respectively). First generation St Croix and Java Fat-tail crosses which had high EPGs (6200 and 4800, respectively) had low weaning weights (9·1 and 8·7 kg), but these weights were higher than that of Sumatra (8·2 kg). PCV of Sumatra and Sumatra × St Croix F2 (27·6 and 27·7) were very similar, but were different from St Croix (24·3). All regressions of weaning weight on EPG were negative, showing that weaning weight is expected to decrease with increasing EPG. The decrease was much higher for Sumatra × Java Fat-tail and St Croix than for Sumatra, Sumatra × St Croix F1 and F2 genotypes. Albers *et al.* (1984) studied Merino lambs aged 3 to 4 months and found that the correlation coefficient between faecal egg counts and live-weight gain when infected by *H. contortus* larvae (dose 11000 infective larvae) was –0·76 ± 0·32.

The regressions of PCV on weaning weight were positive, showing that weaning weight is expected to increase when PCV is high. This finding is similar to that of Albers *et al.* (1990) that live-weight gain in lambs infected with *H. contortus* was positively correlated with haematocrit and negatively correlated with EPG.

In conclusion, the faecal egg counts and packed cell volumes were found to be good indicators of naturally acquired nematode infections and egg counts were negatively correlated, and PCV positively correlated, with weaning weight of the lambs. The hair sheep breeds, such as St Croix and Barbados Blackbelly, may be used in cross breeding with small woolled local sheep to produce animals of larger body size and lower nematode worm burden. Further improvements may be made by selection of crossbred animals with low egg counts and higher body weight.

Acknowledgements

Grateful thanks are due to Leo Batubara, Director, Institute for Animal Production, Sungai Putih, North Sumatra and Dr G. E. Bradford, University of California, Davis for their continuous interest and assistance in this research programme.

The work was supported by the Small Ruminant Collaborative Research Support Programme funded by the United States Agency for International Development and by the Science, Research and Development programme (STD3: TS3 - CT92 - 0073) of the European Union coordinated by the Institute of Tropical Medicine, Antwerp, Belgium.

References

Albers, G. A. A., Burgess, S. E., Adams, D. B., Barker, J. S. F., Le Jambre, L. F. and Piper, L. R. 1984. Breeding *Haemonchus contortus* resistant sheep — problems and prospects. In *Immunogenetic approaches to the control of endoparasites, with particular reference to parasites of sheep* (ed. J. K. Dineen and P. M. Outteridge), pp. 41-51. CSIRO Division of Animal Health, Melbourne.

Albers, G. A. A., Gray, G. D., Le Jambre, L. F., Barger, I. A. and Barker, J. S. F. 1990. The effect of *Haemonchus contortus* infection on haematological parameters in young Merino sheep and its significance for productivity. *Animal Production* **50:** 99-109.

Courtney, C. H., Parker, C. F., McClure, K. E. and Herd, R. M. 1985. Resistance of exotic and domestic lambs to experimental infection with *Haemonchus contortus. International Journal for Parasitology* **15:** 101-109.

Devendra, C. 1991. Potential integration of small ruminant with tree cropping systems in South East Asia and South Pacific. *World Animal Review* **66:** 13-22.

Dorny, P., Symoens, C., Jalila, A., Vercruysse, J. and Sani, R. 1994. Strongyle infections in sheep and goats under the traditional husbandry system in Peninsular, Malaysia. *Veterinary Parasitology* **56:** 121-136.

Douch, P. G. C. and Morum, P. E. 1993. The effect of age on the response of Romney sheep to gastrointestinal nematodes during grazing. *International Journal for Parasitology* **23:** 651-655.

Gray, G. D. 1991. Breeding for resistance to trichostrongyle nematodes in sheep. In *Breeding for disease resistance in farm animals* (ed. J. B. Owen and R. F. E. Axford), pp. 139-161. CAB International, Wallingford.

Gray, G. D., Barger, I. A., Le Jambre, L. F. and Douch, G. C. 1992. Parasitological and immunological responses of genetically resistant Merino sheep on pastures contaminated with parasitic nematodes. *International Journal for Parasitology* **22:** 417-425.

Gray, G. D., Woolaston, R. R. and Eaton, B. T. 1995. *Breeding for resistance to infectious diseases in small ruminants.* ACIAR, Canberra.

Gruner, L. 1991. Breeding for helminth resistance in sheep and goats. In *Breeding for disease resistance in farm animals* (ed. J. B. Owen and R. F. E. Axford), pp. 187-200. CAB International, Wallingford.

Handayani, S. W. and Gatenby, R. M. 1988. Effects of management system, legume feeding and anthelmintic treatment on the performance of lambs in North Sumatra. *Tropical Animal Health and Production* **20:** 122-128.

Ikeme, M. M., Fatimah, I. and Lee, C. C. 1987. Seasonal changes in the prevalence of *Haemonchus* and *Trichostrongylus* hypobiotic larvae in tracer goats in Malaysia. *Tropical Animal Health and Production* **19**: 184-190.

Kassai, T. and Sreter, T. 1992. Genetic aspects of the host resistance to helminthic infections. *Research and Reviews in Parasitology* **52:** 67-75.

Pandey, V. S. and Sivaraj, S. 1994. Anthelmintic resistance in *Haemonchus contortus* from sheep in Malaysia. *Veterinary Parasitology* **53:** 67-74.

Pandey, V. S., Verhulst, A., Gatenby, R. M., Saithanoo, S., Barcelo, P. and Monteiro, L. S. 1994. Genetic resistance to internal parasites in sheep and goats and its exploitation for increasing animal productivity in Southeast Asia: an example of international collaborative research. In *Strategic development for small ruminant production in Asia Pacific* (ed. Subandriyo and R. M. Gatenby), pp. 39-50. *SR-CRSP, University of California, Davis.*

Sivaraj, S., Dorny, P., Vercruysse, J. and Pandey, V. S. 1994. Multiple and multigeneric anthelmintic resistance on a sheep farm in Malaysia. *Veterinary Parasitology* **55:** 159-165.

Sivaraj, S. and Pandey, V. S. 1994. Isolation of ivermectin resistant strain of *Haemonchus contortus* from sheep in Malaysia. *Veterinary Record* **135:** 307-308.

Sreter, T., Molnar, V. and Kassai, T. 1994. The distribution of nematode egg counts and larval counts in grazing sheep and their implications for parasite control. *International Journal for Parasitology* 24: 103-108.

Statistical Analysis Systems Institute. 1987. *SAS/STAT guide for personal computers, version 6.* Statistical Analysis Systems Institute Inc., Cary, NC.

Wakelin, D. 1992. Genetic variation in resistance to parasitic infection: experimental approaches and practical applications. *Research in Veterinary Science* **53:**139-147.

Windon, R. G. 1990. Selective breeding for the control of nematodiasis in sheep. *Revues Scientifiques et Techniques de l'Office International des Epizooties* **2:** 555-576.

Windon, R. G. and Dineen, J. K. 1981. The effect of selection of both sire and dam on the response of F1 generation lambs to vaccination with irradiated *Trichostrongylus colubriformis* larvae. *International Journal for Parasitology* **11:** 11-16.

Woolaston, R. R. 1990. Genetic improvement of resistance to internal parasites in sheep. *Wool Technology and Sheep Breeding* **38:** 1-6.

Woolaston, R. R., Barger, I. A. and Piper, L. R. 1990. Response to helminth infection of sheep selected for resistance to *Haemonchus contortus. International Journal for Parasitology* **20:** 1015-1018.

Yazwinski, T. A., Goode, L., Moncol, D. J., Morgan, G. W. and Linnerud, A. C. 1981. *Haemonchus contortus* resistance in straightbred and crossbred Barbados Blackbelly sheep. *Journal of Animal Science* **51:** 279-284.

Zajac, A. M., Krakowka, S., Herd, R. P. and McClure, K. E. 1990. Experimental *Haemonchus contortus* infection in three breeds of sheep. *Veterinary Parasitology* **36:** 221-235.

(*Received* 27 *June* 1995—*Accepted* 5 *August* 1996)