Genetic parameters for resistance to *Haemonchus contortus* in Merino sheep in South Africa

S W Nieuwoudt[a], H E Theron[a] and L P Krüger[a]

ABSTRACT

Resistance to natural infections of *Haemonchus contortus* (wireworm) was studied in Merino sheep. From February 1995 to July 1996 data were collected from the OTK Merino Stud on the farm Wildebeesfontein near Hendrina in Mpumalanga province. From March 1998 to January 2000 another Merino flock at Irene in Gauteng province was included in the study. In both cases, 50 randomly-chosen animals from each group of lambs weaned were sampled weekly for faecal egg count (FEC) until a mean of 2500 eggs per gram faeces (epg) was reached. At this stage, all lambs in the group were sampled for FEC, packed cell volume (PCV) and live mass in the case of the Wildebeesfontein flock. Animals were monitored from weaning to about 1 year of age. Data from 5 different groups of lambs (583 animals and 1722 records in total) with genetic links were accumulated and analysed. Variance components and resulting heritabilities for logFEC and PCV were estimated using a bivariate animal model with repeated records. The estimated heritabilities were 0.24 ± 0.02 for logFEC and 0.14 ± 0.02 for PCV. A strong negative correlation (–0.84 ± 0.06) existed between the 2 traits. The genetic correlation between PCV and live mass for the Wildebeesfontein flock was low (0.28 ± 0.09), while that between logFEC and live mass was negative, although not significantly different from zero (–0.13 ± 0.09). These results suggest that FEC can be used as a selection criterion for resistance to *H. contortus* infections in Merino sheep.

Key words: genetic parameters, *Haemonchus contortus,* Merino sheep, resistance.

Nieuwoudt S W, Theron H E, Krüger L P **Genetic parameters for resistance to** *Haemonchus contortus* **in Merino sheep in South Africa**. *Journal of the South African Veterinary Association* (2002) 73(1): 4–7 (En.). ARC-Animal Improvement Institute, Private Bag X2, Irene, 0062 South Africa.

INTRODUCTION

If uncontrolled, infection with internal nematode parasites may lead to serious production losses and even death of animals. Over the last few decades new and better drugs have been developed, and these have often been used as the only means of control against worms in sheep. The continued use of these anthelmintic treatments has now brought the sheep industry to the point where parasitic nematodes have developed resistance to all of the main classes of anthelmintics and there are very limited management options available to control these parasites. Surveys in South Africa have indicated that about 90 % of sheep farms harbour strains of nematodes that are resistant to drugs from at least 1 of the 5 available anthelmintic groups. In at least 2 cases, resistance to all 5 anthelmintic groups was demonstrated[21]. In most sheep-producing areas where internal parasites are a chronic problem, there is increasing pressure for alternative control strategies such as breeding parasite-resistant animals. This means that, in order to ensure their own survival, sheep farmers will have to modify selection for production traits to also increase the ability of their sheep to withstand worm challenge, in addition to using other methods aimed at reduced selection for resistant worms.

Studies on breeding for resistance to internal parasites in sheep have been in progress in Australia[25], New Zealand[14], Kenya[3], France[13], the UK[6], the USA[9] and Indonesia[17] for a number of years, and the results predict a fair amount of success for similar programmes in South Africa. This report covers part of an investigation aimed at examining the heritability of resistance of the South African Merino population to infestation with parasitic nematodes as a first step towards consideration of the trait in commercial breeding programmes in South Africa.

MATERIALS AND METHODS

Animals

Two different flocks of Merino sheep were included in the study. From February 1995 to July 1996 data were collected from all lambs weaned from the OTK Merino Stud on the farm Wildebeesfontein near Hendrina in Mpumalanga province. This comprised 1 group (born during spring 1994) monitored from February 1995 to January 1996, a 2nd group (born during autumn 1995) from September 1995 to April 1996, and a 3rd group (born during spring 1995) from February 1996 to July 1996. These animals were grazed alternatively on natural and artificial pastures as well as harvested maize fields and sexes were separated at weaning.

The 2nd flock consisted of 5 rams from the Wildebeesfontein flock mated to Merino ewes kept at Irene in Gauteng province. Weaners from this flock (born during spring 1997 and spring 1998) were monitored from March 1998 to January 1999 and March 1999 to January 2000 respectively. This flock was also separated according to sex, but grazed on similar kikuyu pastures in adjacent camps, with additional hay fed from May to October. Pedigree records were available for all animals in both flocks.

Trial protocol

Resistance to nematode parasites was assessed on the basis of faecal egg counts (FECs) and packed cell volumes (PCVs) following natural infection of weaners. Faecal egg counts were performed using a modified McMaster method[19], with counts expressed in eggs per gram (epg) and a sensitivity of 100 eggs per egg counted. Packed cell volumes were determined by micro-centrifugation of blood taken from the jugular vein and expressed as percentage red blood cells in whole blood[8]. Although FEC gives a more direct indication of levels of worm infection in individual animals, PCV indicates levels of anaemia caused by blood-sucking parasites. It therefore also serves as an indirect indication of especially severe infections of parasites such as *Haemonchus contortus.*

A subsample of 50 animals from each group was screened weekly for FEC until a mean of 2500 epg was reached, when all lambs in the group were sampled for FEC and PCV and then drenched. Wildebees-

---

[a] ARC-Animal Improvement Institute, Private Bag X2, Irene, 0062 South Africa.

Received: December 2000. Accepted: January 2001.

Table 1: **Average logFEC and PCV for the different groups of lambs used in the study, presented according to locality, group, sampling time and sex.**

Locality	Group	YRWK	Rams			Ewes		
			n	Average PCV ± SD	Average LogFEC ± SD	*n*	Average PCV ± SD	Average LogFEC ± SD
WBF	Spr '94	9513	56	31.4 ± 3.7	8.5 ± 1.2	59	33.2 ± 3.7	8.6 ± 0.6
		9522	50	30.6 ± 3.3	7.3 ± 0.8	51	30.7 ± 3.4	7.0 ± 0.8
		9536	49	33.8 ± 2.3	6.4 ± 1.9	52	32.7 ± 3.6	6.6 ± 2.4
		9604	47	28.6 ± 2.6	6.0 ± 1.7	51	32.2 ± 2.9	5.5 ± 2.2
WBF	Aut '95	9604	68	27.1 ± 3.6	6.8 ± 1.2	69	39.1 ± 4.5	5.6 ± 2.6
		9608	61	27.8 ± 5.6	8.1 ± 0.8	8	26.0 ± 8.7	8.5 ± 1.1
		9614	67	24.0 ± 3.6	9.0 ± 0.9	62	27.3 ± 3.9	8.6 ± 1.0
WBF	Spr '95	9607	61		7.9 ± 2.5	60		6.7 ± 3.2
		9612	78	26.8 ± 4.9	6.5 ± 2.8	67	29.6 ± 5.2	5.5 ± 3.0
		9620	77	29.6 ± 3.8	7.6 ± 1.2	70	32.3 ± 3.8	7.0 ± 1.6
Irene	Spr '97	9817	32	22.7 ± 4.2	8.4 ± 1.6	35	24.0 ± 4.4	7.7 ± 1.1
		9838	32	25.7 ± 3.8	7.5 ± 0.5	35	27.4 ± 3.6	5.6 ± 2.2
		9901	30	23.3 ± 6.1	8.6 ± 1.2	35	28.4 ± 5.4	7.2 ± 2.0
Irene	Spr '98	9906	30	25.8 ± 4.9	7.9 ± 1.6	42	29.5 ± 4.3	7.1 ± 1.5
		9910	30	25.2 ± 4.0	8.1 ± 0.7	42	26.1 ± 3.8	8.2 ± 0.7
		9921	30	30.3 ± 5.0	8.1 ± 0.9	42	27.9 ± 4.3	7.3 ± 2.5
		9943	30	24.1 ± 3.8	7.0 ± 2.3	42	30.1 ± 3.0	4.2 ± 2.8
		2003	30	27.8 ± 3.5	7.5 ± 1.1	42	30.5 ± 2.3	5.1 ± 2.4

WBF = Wildebeesfontein; Spr = Spring; Aut = Autumn; YRWK = year and week when sampled.

fontein animals were also weighed at this stage. Pooled faecal samples were used to prepare larval cultures from which larvae were identified to determine the generic composition of nematode populations. The entire procedure was repeated over the periods mentioned above for each group of lambs.

Statistical analysis

Faecal egg counts were logarithmically transformed ($\log_e$) to normalise the skewed distribution and a value of 1 was substituted for each nil value when no eggs were counted from a sample. Data obtained from the 3 groups of weaners at Wildebeesfontein and 2 at Irene were accumulated. At Wildebeesfontein, sires were common between spring 1994 and autumn 1995, and dams between spring 1994 and spring 1995 , while 5 of the male offspring from Wildebeesfontein were used as sires at Irene, thus creating genetic links between all the groups.

Non-genetic effects were tested in an analysis of variance, using SAS[18]. Sire was treated as a random effect, while the contemporary group year-week (year and week of the year when sampled), sex and birth type (twin/single) were treated as fixed effects. Live mass was not recorded in the Irene flock and birth dates were not recorded in the Wildebeesfontein flock. Although birth dates were not included in the analysis, all lambs per group were born within a period of 60 days and were considered to be of the same age.

Variance components and resulting heritabilities for logFEC and PCV were estimated by means of VCE4[12] using a bivariate animal model with repeated records and fitting the significant effects identified from the analyses of variance. The following model was fitted:

$y = x_b + z_a + e$

where y = vector of observed traits of animals; b = vector of fixed effects (year-week and sex); a = vector of direct additive genetic effects; x_1 z = corresponding incidence matrices relating the effects to y, and e = vector of residuals.

The genetic correlations between logFEC, PCV, and live mass (in the case of Wildebeesfontein) were estimated.

RESULTS

In total, data for 583 animals and 1722 records (3–5 repetitions per group) were analysed. The numbers per group of lambs, as well as the average logFEC's and PCV's for every group of lambs at every sampling time, are presented in Table 1. From the analysis of variance, year-week and sex ($P \leq 0.001$) and live mass ($P \leq 0.05$) were shown to be significant sources of variation for PCV, while only sex and year-week ($P \leq 0.001$) caused significant variation in logFEC. These data were used to estimate heritabilities (h^2) for PCV and logFEC, as well as the genetic correlations between traits, as is shown in Table 2. Maternal genetic and permanent environmental effects were not included in the current study. As shown by the log likelihood values, the design was probably inadequate to provide a robust test of these effects.

DISCUSSION

The sex difference indicated by the analysis of variance was confounded by nutrition and management in both flocks, as ram and ewe lambs were grazed separately after weaning. It was therefore not possible to separate these effects from the recorded data. Romjali *et al.*[17], however, found in their study that sex had a significant effect on both PCV and FEC, while Albers *et al.*[1] found no differences between sexes after artificial infection. In both these studies *H. contortus* was the parasite species concerned.

The estimated heritability for logFEC was 0.236 ± 0.022. This result confirms that resistance to *H. contortus* (represented by FEC) is a heritable trait and suggests that South African Merinos should respond favourably to selection.

Table 2: **Estimated heritabilities for resistance traits measured in the Wildebeesfontein and Irene Merino flocks and genetic correlations between different traits. Heritabilities are on the diagonal.**

	PCV	logFEC	Live mass
PCV	0.14 ± 0.02	–0.84 ± 0.06	0.28 ± 0.09
logFEC		0.24 ± 0.02	–0.13 ± 0.09

This heritability estimate is also similar to those from other studies, which range on average between 0.2 and 0.4[1–3,7]. In a number of Australian studies[1,24,26,27], an artificial infection of animals was preferred to a natural challenge from infected pastures, as was the case in other studies[3,6,7,10] and the present study. The mode of infection, however, had no significant influence on the results of these studies. Selection based on these estimations under both natural and artificial parasite challenge has led to successful reductions in levels of internal parasite infections in flocks of sheep in Australia and New Zealand, where resistant lines have been bred against *Trichostrongylus colubriformis*[10,22,23] and *H. contortus*[27].

The heritability for PCV was estimated at 0.139 ± 0.022. Other studies have shown heritabilities for PCV in the order of 0.4[1] and 0.24 ± 0.16[4]. According to Baker[2], the average heritability for a single PCV measurement from 14 Australian and New Zealand studies was 0.35, which is similar to that for FEC (0.32) from the same studies. Romjali *et al.*[17] concluded that both FEC and PCV are good indicators of naturally-acquired nematode infections. The lower heritability for PCV for the current study is probably due to relatively low infections of wireworm that resulted in limited variation in PCV values.

A strong negative genetic correlation (–0.835 ± 0.059) existed between logFEC and PCV. Larval identifications indicated *Haemonchus* spp. (wireworm, a blood-sucking parasite) as the only or main nematode species present in the flocks. Infection by blood-sucking parasites leads to anaemia that is indicated by lower PCV, which explains the negative correlation. The correlation further suggests a common genetic control for the 2 traits and implies that scoring of anaemia on the colour of eye mucous membranes can be used as an indication of levels of *Haemonchus* infection as proposed by Van Wyk *et al.*[20]. Similar high genetic correlations of –0.86 ± 0.28, –0.99 and –0.87 were reported between FEC and PCV by Albers *et al.*[1], Baker *et al.*[4] and Woolaston and Piper[26] respectively.

The genetic correlation between PCV and live mass for the Wildebeesfontein flock was low (0.28 ± 0.09), while that between logFEC and live mass was negative, although not significantly different from zero (–0.13 ± 0.09). This is in agreement with Baker *et al.*[5], who found that correlations between logFEC and live-mass gain in sheep on farms in New Zealand did not differ significantly from zero. In this case *Trichostrongylus* and *Ostertagia* were the most prevalent parasitic genera. Negative correlations between logFEC of *Ostertagia circumcincta* and live mass, ranging from –0.63 ± 0.32 to –0.90 ± 0.28 were reported by Bishop *et al.*[6]. Romjali *et al.*[17] found that weaning mass of lambs decreases with increasing FEC (negative correlation) and increases with increasing PCV (positive correlation) where *H. contortus* was the main parasite species present. Watson *et al.*[22] and Bisset *et al.*[7] also reported negative correlations of –0.43 and –0.48 ± 0.21 respectively between FEC and live mass gain in lambs. In both these studies *Trichostrongylus* was the main parasite concerned.

There have been some reports of unfavourable correlations between resistance to internal parasites and production traits. Morris *et al.*[16] compared FEC from 5 Romney selection lines to controls while being run together at a single site. The average FEC for 1 of the 3 lines selected for body mass was 63 % higher, although the other 2 were not significantly different from the controls. In the case of the 2 lines selected for fleece mass, the average FEC was significantly greater than that of the controls by 35 and 46 % respectively. In addition, Morris *et al.*[15] found that single-trait selection for reduced FEC in Romney and Perrendale sheep is associated with reduced greasy fleece mass in 3 selection lines in New Zealand. McEwan *et al.*[14], on the other hand, found strong positive correlations between reduced FEC and live mass gain (0.95) and wool growth (0.41) in New Zealand Romney sheep. Greeff *et* al.[11] found that selection for low faecal egg count did not result in any unfavourable changes in hogget body mass, clean fleece mass, or fibre diameter in the Rylington Merino selection line in Australia.

Preliminary evidence suggests that breeding for resistance to internal parasites in sheep might be one of the few remaining options for roundworm control. The results obtained so far from the present study also indicate that it may be feasible to include resistance to internal parasites in a multi-trait breeding objective under South African conditions. It should, however, be kept in mind that selective breeding will only yield long-term results, while the state of resistance in the country requires fast action in addition. Breeding for resistance to internal parasites should therefore be considered as part of a broader integrated control programme.

ACKNOWLEDGEMENTS

This study was funded by the Meat Board, Red Meat Research and Development Trust, Agricultural Research Council and OTK. Technical support was provided by OTK and ARC-Onderstepoort Veterinary Institute.

REFERENCES

1. Albers G A A, Gray G D, Piper L R, Barker J S F, Le Jambre L F, Barger I A 1987 The genetics of resistance and resilience to *Haemonchus contortus* infection in young Merino sheep. *International Journal for Parasitology* 17(7): 1355–1363
2. Baker R L 1995 Genetics of disease resistance in small ruminants in Africa. In Gray G D, Woolaston R R, Eaton B T (eds) *Breeding for resistance to infectious diseases of small ruminants.* ACIAR Monograph no. 34, Canberra: 120–138
3. Baker R L, Mwamachi D M, Audho J O, Thorpe W 1994 Genetic resistance to gastro-intestinal nematode parasites in Red Maasai sheep in Kenya. *Proceedings of the 5th World Congress on Genetics Applied to Livestock Production, Guelph, Canada,* 7–12 August 1994: 277–280
4. Baker R L, Reynolds L, Mwamachi D M, Ouma J, Magadi M, Miller J E 1993 Genetic resistance to gastrointestinal parasites in Dorper and Red Maasai × Dorper lambs in coastal Kenya. *Proceedings of the 11th Scientific Workshop of the Small Ruminant Collaborative Research Support Programme, Nairobi, Kenya,* 3–4 March 1993
5. Baker R L, Watson T G, Bisset S A, Vlassoff A, Douch P G C 1991 Breeding sheep in New Zealand for resistance to internal parasites: research results and commercial application. In Gray G D, Woolaston R R (eds) *Breeding for disease resistance in sheep.* Australian Wool Corporation, Melbourne: 19–32
6. Bishop S C, Bairden K, McKellar Q A, Park M, Stear M J 1996 Genetic parameters for faecal egg count following mixed, natural, predominantly *Ostertagia circumcincta* infection and relationships with live weight in young lambs. *Animal Science* 63: 423–428
7. Bisset S A, Vlassoff A, Morris C A, Southey B R, Baker R L, Parker A G H 1992 Heritability of and genetic correlations among faecal egg counts and productivity traits in Romney sheep. *New Zealand Journal of Agricultural Research* 35: 51–58
8. Coles E H 1967 *Veterinary clinical pathology.* W B Saunders Company, Philadelphia
9. Courtney C H, Parker C F, McClure K E, Herd R P 1985 Resistance of exotic and domestic lambs to experimental infection with *Haemonchus contortus. International Journal for Parasitology* 15: 101–109
10. Douch P G C, Green R S, Morris C A, Bisset S A, Vlassoff A, Baker R L, Watson T G, Hurford A P, Wheeler M 1995 Genetic and phenotypic relationships among anti-*Trichostrongylus colubriformis* antibody level, faecal egg count and body weight traits in grazing Romney sheep. *Livestock Production Science* 41: 121–132
11. Greeff J C, Karlsson L J E, Bessier R B 1999 Breeding sheep for resistance to internal parasites. *Proceedings of the Association for the Advancement of Animal Breeding and Genetics* 13: 150–155
12. Groeneveld E 1997 *REML VCE4. User's guide and reference manual.* Federal Agricultural Research Centre, Neustadt, Germany
13. Gruner L, Cabaret J, Sauve C, Pailhories R 1986 Comparative susceptibility of Romanov and Lacaune sheep to gastrointestinal nematodes and small lungworms.

Veterinary Parasitology 19: 85–93

14. McEwan J C, Mason P, Baker R L, Clarke J N, Hickey S M, Turner K 1992 Effects of selection for productive traits on internal parasite resistance in sheep. *Proceedings of the New Zealand Society of Animal Production* 52: 53–56
15. Morris C A, Bisset S A, Vlassoff A, Baker R L, Watson T G, Leathwick D M, Wheeler M 1997 Correlated responses in fleece weight to selection for divergence in faecal nematode egg count in New Zealand Romneys and Perrendales. *Proceedings of the New Zealand Society of Animal Production* 57: 26–28
16. Morris C A, Clarke J N, Watson T G, Wrigglesworth A L, Dobbie J L 1996 Faecal egg count and food intake comparisons of Romney single-trait selection and control lines. *New Zealand Journal of Agricultural Research* 39: 371–378
17. Romjali E, Pandey V S, Gatenby R M, Doloksaribu M, Sakul H, Wilson A, Verhulst A 1997 Genetic resistance of different genotypes of sheep to natural infections with gastro-intestinal nematodes. *Animal Science* 64: 97–104
18. SAS Institute Inc. 1989 *SAS/STAT® user's guide* (ver. 6, 4th edn, vol. 2.) SAS Institute, Cary, NC
19. Thienpont D, Rochette F, Vanparijs O F J 1986 *Diagnosing helminthiasis by coprological examination.* Janssen Research Foundation, Beerse, Belgium
20. Vn Wyk J A, Malan F S, Bath G F 1997 Rampant anthelmintic resistance in sheep in South Africa – what are the options? *Proceedings of Workshop held at the 16th International Conference of the World Association for the Advancement of Veterinary Parasitology, Sun City, South Africa,* 10–15 August 1997: 51–60
21. Van Wyk J A, Malan F S, Randles J L 1997 How long before resistance makes it impossible to control some field strains of *Haemonchus contortus* in South Africa with any of the modern anthelmintics? *Veterinary Parasitology* 70: 111–122
22. Watson T G, Baker R L, Harvey T G 1986 Genetic variation in resistance or tolerance to internal nematode parasites in strains of sheep at Rotomahana. *Proceedings of the New Zealand Society of Animal Production* 46: 23–26
23. Windon R G 1991 Resistance mechanisms in the *Trichostrongylus* selection flock. In Gray G D, Woolaston R R (eds) *Breeding for disease resistance in sheep.* Australian Wool Corporation, Melbourne: 77–86
24. Woolaston R R 1990 Genetic improvement of resistance to internal parasites in sheep. *Proceedings of the Australian Association for Animal Breeding and Genetics* 8: 163–171
25. Woolaston R R 1992 Selection of Merino sheep for increased and decreased resistance to *Haemonchus contortus*: peri-parturient effects on faecal egg counts. *International Journal for Parasitology* 22(7): 947–953
26. Woolaston R R, Piper L R 1996 Selection of Merino sheep for resistance to *Haemonchus contortus*: genetic variation. *Animal Science* 62: 451–460
27. Woolaston R R, Windon, R G, Gray G D 1991 Genetic variation in resistance to internal parasites in Armidale experimental flocks. In Gray G D, Woolaston R R (eds) *Breeding for disease resistance in sheep.* Australian Wool Corporation, Melbourne: 1–9