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Genetic studies of resilience of Romney sheep to nematode challenge in New Zealand

C.A. MORRIS, S.A. BISSET¹, A. VLASSOFF¹, A.D. MACKAY², K. BETTERIDGE²,
M.J. ALDERTON, C.J. WEST¹ AND B.P. DEVANTIER²

AgResearch, Ruakura Agricultural Research Centre, PB 3123, Hamilton, New Zealand

ABSTRACT

“Resilience” in sheep can be defined as the ability to withstand nematode challenge, and to maintain acceptable health and productivity, with minimal reliance on anthelmintic treatment. One heritable component trait is Total Drench Requirement (TDR), which is measured in lambs managed on a regime of “drench-on-demand” (where *Trichostrongylus* and *Ostertagia* are the predominant nematode genera in New Zealand sheep). A breeding experiment was established in 1994, selecting for increased resilience in Romney lambs. Currently, breeding ewes in the experiment are subdivided between Ballantrae, where four genetically equivalent sub-groups graze separate farmlets year-round, under Non-Chemical versus Conventional management (AgResearch’s Low-Chemical Farming Systems Programme), and Wallaceville, where an Elite Resilient line was re-established in 1999 alongside the Control Faecal Egg Count (FEC) line. Selection responses up to 1999/00 in the Elite Resilient-line lambs (relative to the Control line) included a 27% greater post-weaning weight gain (GAIN: Dec. to Apr.), a 0.48 unit reduction in dags, and a 45% reduction in TDR (Dec. to Apr.). A favourable genetic correlation (-0.54) was recorded between TDR and GAIN in lambs, whilst that between TDR and log FEC was -0.17 (not significant). Mean autumn weights in lambs at Ballantrae were 5.8 kg (18%) lower in the Non-Chemical than Conventional treatment groups ($P < 0.01$). Through intense genetic selection, 51% of Elite-line ram lambs are now resilient enough for low-chemical or organic production systems.

Keywords: sheep; nematodes; resilience; genetics.

INTRODUCTION

Breeding sheep with a greater ability to cope with roundworm challenge is one of several options that may assist farmers in New Zealand to both manage the growing anthelmintic resistance problem and meet consumer demands to minimise drug usage in livestock. Two different types of host response, “resistance” and “resilience”, may contribute to this ability (Albers *et al.*, 1987). Resistant lambs can maintain low worm burdens while grazing pasture contaminated with worm larvae, but may not have good growth or fleece weights (see below). However, resilient lambs can maintain good health and growth rates without worm treatment while grazing contaminated pasture.

Most genetic studies to date have focused on host resistance, using faecal worm egg count (FEC) as an *ante-mortem* indicator of the trait. In Merinos in Australia and South Africa, where the predominant roundworm species is usually *Haemonchus contortus*, a favourable genetic relationship has been observed between host resistance and resilience (Albers *et al.*, 1987; Bisset *et al.*, 2001). This suggests that selection for either would achieve a similar endpoint. However, in dual purpose breeds in New Zealand, where the predominant roundworm genera are *Trichostrongylus* and *Ostertagia*, the relationship between the above traits has proved to be more complex (Bisset & Morris, 1996).

Genetic studies of resilience in New Zealand began in 1991, using private ram breeding flocks of Romneys in the Hawkes Bay/Wairarapa regions, and experimental flocks at Wallaceville (WVL) Animal Research Centre. Approximately 14000 lambs were involved (1991-93 lamb crops), representing 213 different sire groups. These studies, which utilised a “drench-on-demand” procedure to identify the most resilient lambs without seriously

jeopardising the health of their less resilient flockmates, have provided data for genetic parameters, as published by Bisset *et al.* (1994, 1996) and Bisset & Morris (1996). An experimental Romney breeding line, selected for resilience to roundworm challenge, has subsequently been established by AgResearch for more detailed studies of the trait to be undertaken (Morris & Bisset, 1996).

The objectives of this paper are to review genetic parameter estimates for resilience, report on genetic progress in the selection line, summarise correlated responses to date, and compare the performance of animals under replicated “Conventional” and “Non-Chemical” management systems.

MATERIALS AND METHODS

Resilience selection lines

In 1994 high (H) and low (L) resilience selection lines were set up at WVL, using rams of high or low breeding value (BV) for resilience identified from the 1991-93 data above, and ewes screened on BV for resilience as lambs (approx. 100 ewes per line) from other WVL studies (Morris & Bisset, 1996). The L line was discontinued after two years, but further selection was applied in the H line at WVL in 1995 and 1996, and from 1997 onwards in an expanded trial at Ballantrae (BLT).

The BLT trial is part of AgResearch’s Low Chemical Farming Systems Programme, comprising four replicated farmlets of 90 H-line ewes each, with two farmlets managed under “Conventional” farming, and two under a “Non-Chemical” system (Mackay *et al.*, 1998). Genetic selection for increased resilience is applied in all farmlets (treated genetically as one line by using equivalent groups of rams on BV in each farmlet), with repeated reference sires included across years and farmlets. In 1999, an Elite resilient line (‘E’) of approx. 65 ewes was screened from

¹AgResearch, Wallaceville Animal Research Centre, PO Box 40 063, Upper Hutt, New Zealand.

²AgResearch, Grasslands, Private Bag 11008, Palmerston North, New Zealand.

the four BLT groups and transferred back to WVL, where it has since been maintained under selection alongside the WVL Control ('C') FEC line (Morris *et al.*, 2000). Rams at both sites of this trial were selected each year using restricted maximum likelihood (REML) procedures (Gilmour, 1997).

Recording and selection procedures

Lamb weights (both sexes) were recorded at weaning in December, and all lambs other than the females on the Non-Chemical farmlets were drenched at this time. From weaning, ewe and ram lambs grazed as separate flocks under natural worm challenge.

From the 1997-born crop onwards, ram lambs from the four BLT groups were transported to WVL each year immediately after weaning, to be evaluated for resilience until April/May alongside ram lambs from the WVL C line, and (from the 1999 crop onwards) against the E line also. The evaluation procedure was as follows: from 4-6 weeks post-weaning all ram lambs were mustered regularly (initially at about fortnightly intervals but at least weekly during peak worm challenge) for weighing and anthelmintic drench treatment on an individual basis if deemed necessary. Following each mustering all lambs were returned to pasture again. The identity of those requiring treatment was recorded. Decision rules for drenching were modified over time; criteria used in the initial studies involving commercial ram breeding flocks were discussed by Bisset & Morris (1996), but currently only those that have lost body weight since last weighing are drenched. The genetic selection criterion for rams and ram lambs was a "standardised drench index" (SDI), defined as the difference between (1) the BV for the total number of drenches required (TDR) by individual ram lambs during the test period (expressed in standardised units), and (2) the BV for standardised age at first drench (and normalised to account for zero treatments from the most resilient animals). There is a high genetic correlation (-0.96) between the two traits (Bisset *et al.*, 1994).

All ewe lambs (four groups of the H line at BLT, and the resident lines at WVL) were recorded for gain from weaning until April (Total gain), with all animals from any one management group being drenched at the same time when required. Faecal sampling for FEC was done on all animals in a management group on the same day. BVs for Total gain and for dag score (DS) were calculated in standard deviation units. DS was on a 0 to 4 scale, where 0 = no dags. The two BVs were then combined into a "Gain-dags" index (GDI), by taking the difference between the two standardised BVs. In contrast to the SDI for males which required TDR data, the GDI for females was used not only for ewe lambs, but also for screened-in ewes in 1997 (BLT) and 1999 (WVL).

Anthelmintic was administered routinely to all Conventional-line lambs at BLT from weaning onwards, and slow-release anthelmintic devices were inserted in all Conventional-line ewes immediately before lambing. No chemicals of any description were used on animals or land in the two Non-Chemical farmlets except for ethical reasons (salvage drenching), after which any treated animals were quarantined in a designated quarantine area for twice the withholding period, before being returned to the mob.

Statistical methods

Traits reported here include BVs for TDR, Total gain and DS in lambs, and least-squares means (SAS, 1995) both for \log_e (FEC + 100) in lambs and ewes at BLT, and also for live weights in lambs and fleece weight in hoggets at BLT. Single-trait BVs were calculated using REML for TDR and DS, but a 2-trait REML was used for Gain 1 (from weaning to approx. the end of January) and Gain 2 (from the end of January to April); the observed genetic correlation between Gain 1 and Gain 2 in unculler females was 0.62 ± 0.07 , whilst the phenotypic correlation was 0.03 ± 0.01 . Estimates of genetic progress were calculated by averaging BVs for all animals weaned in each year-of-birth x selection line, and expressing them relative to the WVL C-line BV averages for the appropriate year.

Treatment effects for the Conventional *versus* Non-Chemical management systems were also compared. F ratios for treatment effects were obtained from the ratio of mean squares for 'treatment' and for 'replicate within treatment' in each analysis. Chi-square was used to test for differences in proportions of undrenched animals in each treatment group.

RESULTS

Genetic parameters

Heritability estimates for age at first drench, TDR, Total gain, DS and autumn live weight, using combined data from the current experiment (1994- to 1999-born lambs, so far) and the initial three years of resilience studies (Bisset & Morris, 1996) were: 0.14 ± 0.02 , 0.19 ± 0.04 , 0.32 ± 0.02 , 0.32 ± 0.02 and 0.27 ± 0.03 , respectively. Separate heritabilities for Gain 1 and Gain 2 were 0.26 ± 0.02 and 0.16 ± 0.02 . The estimate for DS was derived from a repeated-record REML analysis, in which the repeatability was 0.42 ± 0.01 . The genetic correlation estimate between TDR (males) and Total gain (females) was -0.54 ± 0.16 (favourable), between Total gain and \log FEC [measured in the WVL FEC lines] 0.08 (2 identical estimates, for two FECs generally recorded in January and April), between TDR (males) and \log FEC (females) -0.17 ± 0.18 , and between TDR (males) and DS (females) 0.53 ± 0.14 .

Selection responses

Drench requirement data for the unselected WVL C, BLT Conventional and Non-Chemical and WVL E lines are presented in Table 1, showing genetic progress since 1994 when selection began. Three times as many E-line as C-line lambs grew without requiring drench treatment over the 4-month test period ($P < 0.01$), and the E line was also superior ($P < 0.05$) to the mean (30%) for all the BLT groups combined. The Conventional *versus* Non-Chemical contrast showed no significant differences in the percentage untreated. Also shown in Table 1 are the least squares means for TDR, with 0.46 fewer drenches required per animal in the E line than in the C line ($P < 0.001$). These TDR results were consistent with the BV (TDR) comparison of 1999-born E-line and C-line animals (not shown).

Averaging the BV (Total gain) from both sexes of 1999-born lambs (already measured) and 2000-born lambs (measurements in progress, predicted here from each lamb's pedigree), the four BLT groups had Total gain BVs of 1.68 kg, and the E line 2.30 kg, relative to the C line. These

TABLE 1: Drench treatments applied at Wallaceville to male progeny from three genetic groups born in 1999; animals born at Ballantrae (and transferred to Wallaceville at weaning) are subdivided into the Conventional and Non-Chemical management treatments of their flock-of-origin.

Line	No. of sire groups	No. of lambs	% untreated by Round 6 (Apr 3)	Total drenches required (TDR) per animal
Control	5	56	16	1.02
Ballantrae:				
Conventional	4	70	24	0.84
Non-Chemical	4	51	37	0.69
Total	8	121	30	0.78
Elite	4			
	3	43	51	0.56

TABLE 2: Effects of Conventional versus Non-Chemical treatment on some performance traits of lambs (1997-1999 lamb crops; both sexes at weaning, and females thereafter) and breeding ewes (1999 and 2000 years).

	No.	Conventional	Non-Chemical	Difference ^a
Lambs				
Weaning weight (kg)	1115	23.9	22.0	1.9*
Post-weaning gain (kg)	621	7.9	4.0	3.9
Autumn weight (kg)	621	32.2	26.4	5.8**
log _e (FEC + 100) ^b	486	5.43	7.31	-1.88*
Hogget fleece weight (kg)	352	2.40	1.61	0.79*
Ewes (2000-year not recorded for Conventional group)				
log _e (FEC + 100) at mating	721	5.65	5.88	-0.23
log _e (FEC + 100) pre-lambing	484	5.49	5.64	-0.15

^a Testing the treatment effect against the replicate-within-treatment mean square.

^b Units: log_e eggs/g; faecal sampled before the first salvage drench [one exception].

cumulative genetic changes were approximately 19 and 27% of the overall mean, respectively. Corresponding cumulative genetic changes for DS (score 1, in January) were -0.36 and -0.48 score units in the BLT and E lines, relative to the C line (1 unit is approx. 1 phenotypic standard deviation). No selection has been applied to FEC, and the average BV (log_e (FEC + 100)) in the 1999-born E-line lambs was not significantly different from that in the C line.

Management treatments

Table 2 presents some performance data from the resilience selection-line animals over all three years of study at BLT, classified by management treatment. In the young stock, weaning weight, autumn weight and fleece weight were significantly heavier, and FEC was significantly lower, in the Conventional than in the Non-Chemical replicates ($P < 0.01$ and 0.05). Differences in postweaning gain were not significant when tested against the replicate-within-treatment mean-square. Back-transformed FECs in the lambs averaged 127 *versus* 1398 eggs/g, respectively. In the breeding ewe flocks, no significant treatment effects on FEC were observed: 184 *versus* 256 eggs/g at mating, and 141 *versus* 182 eggs/g pre-lambing. Larger differences in FEC were found in BLT ewes at docking (not shown), reflecting the use of slow-release devices in Conventional-line ewes.

DISCUSSION

Genetic parameters

Heritability estimates for age at first drench, TDR, Total gain and DS from the first three years of resilience studies (Bisset & Morris, 1996) were 0.14 ± 0.03 , 0.19 ± 0.04 , 0.21 ± 0.02 and 0.23 ± 0.03 . Updated estimates have not changed for age at first drench and TDR, but are now slightly higher at 0.32 for Total gain and also for DS.

Although expressed in terms of drench requirements, TDR essentially reflects weight gain under prolonged roundworm challenge. Not unexpectedly, therefore, the genetic correlation between TDR in males and Total gain in females was relatively high and favourable (-0.54 ± 0.16). However, using TDR had two main advantages over Total gain under challenge as a measure of resilience. Firstly, the “drench-on-demand” approach allowed the most resilient lambs to be subjected to the prolonged roundworm challenge needed without seriously jeopardising the health of the least resilient lambs. Furthermore, it allowed the trait to be expressed in terms of “drench requirements under challenge”, reflecting the ultimate breeding objective - reducing anthelmintic usage. It was also noteworthy that the genetic correlation between TDR in males and dags in females was high and favourable (0.53 ± 0.14), leading to reduced dags, even though most of the selection pressure was on SDI in males (basically two indices of TDR). In contrast, as found earlier, there was still no indication of any significant association between TDR and FEC. In order to capture the potential epidemiological benefits of reducing FEC (and consequently pasture contamination), in addition to increasing resilience, the evidence continues to suggest that (under New Zealand conditions) it will be necessary to select for both traits.

Selection responses

TDR results (reduced by 45% in the E- over the C-line) and the percentage of animals remaining untreated (3-fold higher in the E- than the C-line) confirm that appreciable responses to selection have been achieved over six years. However, reaching this point has involved labour-intensive recording, intense selection across a large Romney resource, and probably considerable losses in the productivity of animals under test. There is, therefore, no general recommendation for farmers to adopt this approach to breeding for reduced drench usage. Nevertheless, 51% of the 1999-born E-line lambs (c.f. 16% of C-line lambs) came through the test period (which covered the autumn peak of roundworm availability on pasture) without receiving a drench treatment (other than one at weaning). Even a difference of this level might reduce selection pressure on anthelmintic resistance according to the results of Barnes *et al.* (1995), who used a modelling approach to investigate the effect on anthelmintic resistance of leaving a proportion of animals untreated.

Management comparison

The most serious and immediate hurdle to an organic or low-chemical farming system is the impact of internal parasites on the growth of young stock (Mackay *et al.*, 1998). In the first three years of the BLT study reported here, the average FEC in lambs was 11 times as high in the Non-Chemical group as in the Conventional group. The

sizes of the associated production penalties are shown in Table 2. A series of decision rules for identifying and treating animals has been highlighted as an integral part of a low-chemical production system during the conversion period (Mackay *et al.*, 2000). Despite the present evidence that a significantly lower proportion of E-line lambs than C-line lambs would have been disqualified in an organic farming situation as a result of salvage drenching, further genetic progress is clearly required for this approach to be viable. We believe that ultimately the most effective breeding strategy for New Zealand conditions will be to breed sheep showing both resistance (i.e., low FEC) and resilience. Such sheep should benefit from the advantages of both traits – namely minimal contamination of pasture with roundworm eggs and maximum productivity in animals with minimal anthelmintic intervention.

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