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Resilience to nematode parasite challenge in industry and AgResearch selection flocks

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ABSTRACT

A large-scale industry project on the resilience of lambs to nematode parasite challenge was undertaken in 2001/02 and 2002/03, to evaluate the feasibility of recording standardised age at first drench (StAge) and postweaning weight gain under nematode challenge, and to estimate genetic differences among flocks. The project involved 15 Romney flocks from two ram breeding groups, with some flocks having been part of an earlier AgResearch study of the genetics of resilience traits. This provided the opportunity to assess any correlated changes in resilience over time (where direct selection over that time period in the industry flocks had been applied to productivity traits, but not to resilience), and to compare the industry performance with AgResearch Resilient-selected and Control lines. The overall estimates of heritability for StAge and weight gain (2 time periods: Gain1 and Gain2) were 0.14 ± 0.014, 0.30 ± 0.015 and 0.15 ± 0.007, respectively. Genetic correlations between StAge and either Gain1 or Gain2 were 0.30 ± 0.06 and 0.41 ± 0.06, respectively. Genetic differences for all traits between the two industry groups were small and not significant. The genetic differences of the current industry-group means (all 15 flocks) above the AgResearch Control line were small (0.8 days, 0.5 kg and 0.9 kg, respectively). In comparison, the genetic differences of the AgResearch Resilient-selected line over the Control line after eight years of selection were 19 days, 0.7 kg and 1.4 kg (11, 8.3 and 9.6% of the industry means). The results confirm that while selection for increased resilience is feasible (although very time-consuming) under commercial conditions, a ram breeder would need to consider an index approach which combined production and resilience traits, to make best use of his animal resources.

Keywords: sheep; nematodes; resilience; genetics; heritability.

INTRODUCTION

Nematode parasitism is one of the most important production and health problems on sheep farms in New Zealand (Vlassoff *et al*., 2001). Breeding sheep with a greater ability to cope with roundworm challenge is one of several options for farmers to manage the growing anthelmintic resistance problem and also to meet consumer demands to minimise drug usage in livestock. There are two different types of desirable animal (host) response to nematode challenge, “resistance” and “resilience” (Albers *et al.,* 1987). Resistant lambs are able to maintain low worm burdens while grazing pasture contaminated with worm larvae, although research in New Zealand has shown that such lambs do not necessarily have good productive performance (see below). Resilient lambs, on the other hand, are able to maintain acceptable health and production without anthelmintic treatment while grazing contaminated pasture, although this does not appear to be the result of lower worm burdens and indeed some resilient lambs may contribute disproportionately to pasture contamination.

In Merino sheep in Australia and South Africa, 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 usually include *Trichostrongylus* and *Ostertagia*, the relationship between resistance and resilience has proved to be more complex (Bisset & Morris, 1996). Most genetic studies to date have focused on host resistance, using faecal worm egg count (FEC) as a live-animal indicator of the trait. Genetic studies of resilience in New Zealand began in 1991/2 and 1992/3, using Romney ram breeding flocks from industry in the Hawke’s Bay/Wairarapa regions, and experimental flocks at AgResearch’s Wallaceville Animal Research Centre. These studies used a “drench-as-required” procedure to identify the most resilient lambs, a protocol which avoids seriously jeopardising the health of their less resilient flock-mates. The resulting data were accumulated and used to estimate genetic parameters (Bisset *et al*., 1994, 1996; Bisset & Morris, 1996).

Beginning in 1994, an AgResearch line of Romney sheep selected for increased resilience was established, alongside an unselected Control (Morris *et al*., 2001). In 2001/02 and 2002/03, 15 Romney ram breeders from two breeder Groups began evaluating a large-scale recording project to rank animals for resilience traits, and to compare genetic groups for resilience. Reference sires linking animals in the two breeder Groups and the AgResearch selection and Control lines were also included.

The objectives of this paper are to estimate heritabilities and genetic correlations for resilience traits, to evaluate genetic differences in resilience between the two Groups of industry flocks and AgResearch’s Control line, and to evaluate genetic progress for resilience in the AgResearch selection experiment relative to the Control line.

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MATERIALS AND METHODS

The Romney breeders' flocks

The ram breeders involved in the study in 2001/02 and 2002/03 were the six members of the Auckland Romney Development Group (ARDG) and the nine members of the Wairarapa Romney Improvement Group (WRIG), with about 30 and 190 sires used per year, respectively. Four of the WRIG flocks were also part of an earlier genetic study by AgResearch (Wallaceville) of resilience in 1991/2 and 1992/3 (Bisset *et al*., 1994, 1996), and their back data were included in our analysis.

The AgResearch Resilient selection lines

The establishment in 1994 and management of AgResearch's high Resilient selection line of Romneys at Wallaceville was summarised by Bisset & Morris (1996) and Morris *et al.* (2001). Briefly, rams in the Resilient line were sib-tested each year for resilience traits (using an animal's own data and his half-sib data) alongside animals from an unselected Control line (Morris *et al*., 2000). This continued at Wallaceville for three years of selection, 1994-1996, with approximately 100 ewes mated per year in each line. In 1997, additional ewes were screened in on a resilience criterion, expanding the flock to create four 90-ewe replicate sub-lines at Ballantrae, which still persist there in 2004. The Ballantrae selection-line ram lambs were transferred to Wallaceville immediately after weaning each year, for evaluation of resilience traits. An Elite Resilient line was generated from the sub-lines in 1999 and returned to Wallaceville, and from that time the Elite line has supplied rams each year for use in the Resilient sub-lines at Ballantrae. In the Elite and the Resilient sub-lines, the genetic selection criterion for rams and ram lambs has been an index combining breeding values (BVs) for standardised age at first drench ("StAge", normalisation being necessary to account for zero drench treatments applied to the most resilient animals), and a closely correlated trait, "total number of drenches required" (Morris *et al*., 2001). Only StAge is evaluated in the present study. Rams in all parts of the trial (AgResearch and industry flocks) have been linked through reference sires, and the rams are ranked here in a combined analysis using restricted maximum likelihood (REML) procedures (Gilmour, 1997) and a full relationship matrix.

Recording procedures at AgResearch and in the breeders' flocks

All ewes were joined in single-sire mating groups, and then grazed together (within flock) over the winter before lambing. All recorded lambs were identified to their dams within 24 hours of birth. A weight was recorded at weaning (WWT) in lambs of both sexes, generally in December.

Recording resilience traits. Recording for resilience traits began at weaning. From this time ewe and ram lambs grazed as separate mobs under natural mixed-species worm challenge. In the AgResearch lines, only ram lambs were recorded for resilience; in the industry flocks, each ram breeder had the choice of whether to use ram or ewe lambs for resilience recording; in 2001, four flock-masters recorded ewe lambs, seven recorded ram lambs and one recorded both, while corresponding counts in 2002 were four, eight and three flocks, respectively. All lambs for resilience recording were drenched at weaning (one industry flock was an exception, where no weaning drench was applied). A weight was taken before differential drenching began (late January/early February), and Gain1 was calculated from WWT and this weight. The resilience evaluation in each research and industry flock was as follows: from 4-6 weeks post-weaning, all lambs were mustered regularly for weighing (initially at about fortnightly intervals, but at least weekly during peak larval challenge), and an anthelmintic drench treatment was administered on an individual basis if deemed necessary. The identities of those requiring a drench treatment were recorded. These procedures for drenching-as-required were repeated over time in each flock. Decision rules for drenching were modified over seasons; criteria used in the initial studies in 1991/92 and 1992/93 in the commercial ram breeding flocks were summarised by Bisset & Morris (1996), but currently only those lambs which gained the least weight (or lost most weight) since last weighing were drenched. In the industry flocks, an average of 30%, 51% and 69% of ARDG lambs were drenched on the first three occasions. Corresponding percentages for WRIG lambs were 30%, 54% and 67%.

Lambs not recorded for resilience. Ewe lambs (from the AgResearch Elite line and two of the Ballantrae sub-lines), and one of the two genders in each industry flock (as chosen by the breeder) were not recorded for resilience. Instead, they were monitored for weight gain from weaning until January/February (Gain1), or from weaning until autumn (March to May, described as Gain2); these weighing endpoints were generally mutually exclusive. *All* animals from any one management group were drenched at the *same* time when the group required it, which was in contrast to the resilience-recorded lambs. The decision on when to drench was based on the breeders' traditional criteria (FECs of monitor animals, or visual assessments of body condition in the group).

Anthelmintic was not administered routinely to ewe lambs in the other two sub-lines at Ballantrae, as they were from farmlets managed on a Non-Chemical basis (animals and land). There were, however, exceptions for individual animals for ethical reasons, where salvage drenching was applied and treated animals were then quarantined in a designated area for twice the withholding period, before being returned to the mob.

Statistical methods

Traits reported here include BVs for StAge, Gain1 and Gain2. For Gain1, some animals were, and some were not, resilience-recorded; for Gain2, most animals were not resilience-recorded. Single-trait BVs were calculated using REML in each case. Two-trait REML analyses were also carried out with pairs of traits: StAge, Gain1 and Gain2. Estimates of genetic progress for each trait were calculated by averaging BVs for all animals weaned in each year-of-birth x selection line, or in each year-of-birth x industry flock. BV results were compared with the Wallaceville Control-line BVs.

RESULTS

Genetic and phenotypic parameters

Table 1 shows the genetic and phenotypic parameter estimates. Heritabilities were low to medium in size, and standard errors of the estimates were small. The genetic correlation between StAge and Gain1 was 0.30 ± 0.06, and between StAge and Gain2 0.41 ± 0.06. The phenotypic correlations between StAge and Gain1 or Gain2 were much smaller than the corresponding genetic correlations. The genetic correlation between Gain1 and Gain2 was high (0.67 ± 0.024), as expected, because of the part-whole nature of the two traits.

TABLE 1: Heritabilities, phenotypic correlations (above the diagonal) and genetic correlations (below the diagonal) for resilience traits from AgResearch lines and the flocks of the Auckland Romney Development Group and the Wairarapa Romney Improvement Group.

Parameter	Age at first drench[1]	Gain1 (kg), weaning to Jan/Feb	Gain2 (kg), weaning to autumn
Age at first drench	0.14±0.014	0.16±0.009	0.06± 0.010
Gain1, weaning to January/February	0.30±0.06	0.30±0.015	0.77±0.003
Gain2, weaning to autumn	0.41±0.06	0.67±0.024	0.15±0.007
Phenotypic standard deviation	38[2]	3.00	3.56
Number of sire groups	658	1027	1501

[1] Standardised for analysis.
[2] Transformed back to units of days.

AgResearch Selection-line responses and Industry Flock differences

Data for StAge (transformed back to the units of measurement), Gain1 and Gain2 are presented in Table 2, along with overall means for each trait. Mean BVs for AgResearch's combined Resilient line (consisting of four sub-lines), the Elite Resilient line and the Control are shown. The combined Resilient line responded to selection by 19 days in StAge above the Controls, as a result of a 5-day screening lift in 1994 and 14 days of progress since then. The Elite Resilient line was superior by 20 days to the Control, and also by 1.3 days to the combined Resilient line. Although Gain1 and Gain2 were not the primary screening traits, screening in 1994 in the combined Resilient line achieved an increase in Gain1 and Gain2 over the Control of 0.57 and 1.18 kg respectively, followed by a further 0.10 and 0.18 kg in the eight years since then. The Elite line was 0.92 and 1.47 kg superior in BV for Gain1 and Gain2 to the Control line in 2002; for Gain2 this margin was 10.4% above the mean of all flocks analysed.

Table 2 also presents the BV means for each trait in the ARDG flocks (2001 and 2002) and the WRIG flocks (1991 and 1992; 2001 and 2002). There were no differences among Groups of flocks in 2001 and 2002, nor between the industry flocks and the AgResearch Control line. Minimal selection had been applied to these traits in most breeders' flocks in the ten years since the original recordings were done in the early 1990s. As a result there was minimal change in StAge over time, but there was an increase in Gain1 and Gain2 over ten years, amounting to about half of that achieved in AgResearch's Elite line over the Control line.

TABLE 2: Average breeding values for resilience traits (expressed as deviations from adjusted means), comparing AgResearch's Control line, the combined Resilient line (consisting of four sub-lines at Ballantrae), and the Elite Resilient line at Wallaceville and the flocks of the Auckland Romney Development Group (ARDG) and the Wairarapa Romney Improvement Group (WRIG).

Line or Group	Age at first drench[1] (days)	Gain1 (kg), weaning to Jan/Feb	Gain2 (kg), weaning to autumn
AgResearch lines			
Control: 1994 to 2002			
Birth years	-0.2	-0.34	-0.50
Resilient (Screened):			
1994 birth year	5.0	0.23	0.68
Resilient Sub-lines:			
2002	18.7	0.33	0.86
Resilient Elite:			
2002	20.0	0.58	0.97
Industry groups			
ARDG:2001 and 2002			
WRIG: 1991 and 1992	0.1	0.06	0.25
2001 and	-1.4	-0.18	-0.21
2002	1.0	0.20	0.52
Overall mean	169	8.1	14.2

[1] Transformed back after analysis to units of days.

The mean value for StAge overall was 169 days (Table 2), and this corresponded to an average interval from weaning to first drench of 93 days in the AgResearch lines and 65 days in the industry flocks (all of these values being conservative because they excluded those lambs still undrenched at the end of the resilience recording period). On average, 22% and 27% of animals in the ARDG and WRIG flocks, respectively, had still not needed a drench at this time.

DISCUSSION

Genetic parameters

The heritability for StAge (0.14) was the same as our previous estimate (Morris *et al*., 2001), in spite of adding many more records to the data file. The heritabilities for Gain1 and Gain2 (0.30 and 0.15, respectively) were similar to those reported by Morris *et al*. (2001) at 0.26 ± 0.02 and 0.16 ± 0.02, although Gain2 in the present analyses was recorded over a longer period (encompassing the Gain1 time period, because of limited numbers of weighing dates in the industry flocks). The reason for the lower heritability over the longer period (Gain 2) is not obvious, but the longer period provided opportunities for more challenges to animals which may affect their liveweight gain, including exposure to endophytes on the pasture. The procedures used for resilience testing, which were a "drench-on-demand" approach, allowed the most resilient lambs to be subjected to prolonged roundworm challenge 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. The genetic correlations between StAge and Gain1 (0.30 ± 0.06), and between StAge and Gain2 (0.41± 0.06) were smaller than the value estimated before, from more limited data (0.61 ± 0.16; Bisset *et al*., 1994). The genetic correlation between Gain1 and Gain2 was high, as expected (0.67 ± 0.024). It was found earlier that the genetic correlation estimate between Gain2 and log FEC was low at 0.08 [as measured in the Wallaceville FEC selection lines in earlier studies: Morris *et al.* (2001)], and it was also low between StAge and log FEC at 0.16 ± 0.18 (Bisset *et al*., 1994), from which it is concluded that to improve FEC and resilience traits at the same time will require selection for both. This appears to be the only way under New Zealand conditions to capture the potential epidemiological benefits of reducing FEC (and consequently reducing pasture contamination), whilst increasing resilience at the same time.

AgResearch Selection-line responses and Industry Flock differences

Results for StAge (increased by 20 days in the Elite over the Control line) confirm that appreciable responses to the initial screening and subsequent selection have been achieved over eight years. The corresponding increase in Gain2 in the Elite line over the Control was 1.47 kg, or 16.9% of the Control-line mean. However, reaching these increases has involved labour-intensive recording, intense selection over a large Romney resource, and almost certainly some 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, we have demonstrated here with a committed group of ram breeders that it is feasible under commercial conditions to record the trait. Further analysis is required to determine the "cost-benefit" of the approach and assess if further refinements are possible to the recording technique.

In view of minimal selection for resilience having been undertaken by WRIG breeders overall since 1991 and 1992, differences were found to be minimal between BVs for StAge then and ten years later. This also implies that the production traits which they have been selecting successfully over that time period (mainly dual-purpose traits in the Sheep Improvement Ltd recording system) were generally uncorrelated with StAge, although there had been a response in Gains 1 and 2, as might be expected because of the associated weight traits which feature in the Sheep Improvement Ltd index. No appreciable genetic differences in resilience traits were found between the ARDG and the WRIG Groups.

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 high resilience. Such sheep should benefit from the advantages of both traits – namely minimal contamination of pasture with roundworm eggs, maximal productivity in animals, and minimal anthelmintic intervention. Whether this will be achieved in the future by selection on performance records or by the use of marker-assisted selection is still uncertain.

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