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Comparison of Romney sheep selected for different roundworm parasite-related traits

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ABSTRACT

Romney sheep selected for resistance to nematode infection, resilience to nematode challenge, or an index combining these traits, were evaluated alongside an unselected control line. Data from lambs born between 2000 and 2006 were analysed. Lambs grazed together, within sexes, while exposed to natural parasite challenge of predominantly *Trichostrongylus* sp. and *Teladorsagia* sp. Relative to the Control, the Resilient line was heavier at weaning (+7.6%) and in autumn (+14.5%), had 5.6% higher yearling greasy fleece weight (YGFW), and less dags (lower score) at 5 months of age by 0.72 standard deviations (SD) (all P <0.01). As expected, the two lines had similar post-weaning faecal worm egg count (FEC1). Compared with the Control, the Resistant line was lighter at weaning (-8.6%) and in autumn (-8.0%), had 14.9% lower YGFW and a higher dag score by 0.22 SD, whilst FEC1 averaged 16% of the Control value (all P <0.001). Performance of the Index line in growth and YGFW was 3.5 to 6.8% above that expected in a Resistant x Resilient cross. Conversely, FEC1 in the Index line was at least 31% higher than expected for a cross. We conclude that combining genes for resilience and low FEC by index selection is feasible.

Keywords: sheep; host resistance; resilience; production traits; nematode parasites.

INTRODUCTION

The high prevalence of anthelmintic resistance on sheep farms in New Zealand (Waghorn *et al*., 2006) is one of the most significant issues facing the sheep industry. Breeding sheep that are less reliant on anthelmintics to maintain health and productivity may assist in managing the problem, as well as meeting consumer demands to minimise drug usage in livestock. Parasite burden, measured in live animals by faecal egg count (FEC), and resilience, measured by production in the face of a parasite challenge, are known to be inherited traits. At AgResearch a single-trait Resistant selection line based on low FEC shows poor lamb production traits compared with its Control line, while a Resilient line has desirable lamb production traits but no reduction in FEC (Bisset *et al*., 2001). This paper reports the results of combining these lines, with the aim of breeding animals less reliant on the intensive use of anthelmintic treatment, demonstrating the trade-offs between production and parasitological traits. The two long-term Romney selection lines above, a cross between them, and the Control line are compared in this report.

MATERIALS AND METHODS

Selection lines

This work was carried out with the approval of the AgResearch Wallaceville and AgResearch Grasslands Animal Ethics Committees.

Information on the performance and progress of the Resistant and Control lines, and an associated Susceptible line, are given by Morris *et al.* (2000). Details of the Resilient line with an Elite and replicate resilient flock, have been published by Morris *et al.* (2004), Mackay *et al.* (2006) and Wheeler *et al.* (2007). Three of the above lines and a new one are compared in this study for a series of lamb performance and parasitological traits:

Line 1: An experimental breeding line of Romney sheep selected for resistance to nematode infection, i.e. selected for a low FEC, initially established at AgResearch, Kaitoke Research Farm in 1979.

Line 2: An unselected control line, which was established subsequently from some of the same foundation stock as the Resistant line. These two lines were moved to AgResearch, Aorangi Research Farm in the summer of 2006/07.

Line 3: In 1994 when it became clear that resistance to infection did not necessarily equate to “resistance to the effects of worm challenge”, an additional breeding line selected for increased resilience to nematode challenge was established at Kaitoke. Resilience in this context is defined as the ability to maintain acceptable health and production, with minimal recourse to anthelmintic treatment, while grazing parasite-contaminated pasture. The observed response is unrelated to a lower worm burden, the distribution of FECs in the Resilient line lambs being similar to that in the Control line lambs. The Resilient line breeding ewes are subdivided into two separate flocks. An “Elite” flock, the results from which are reported in this paper, is maintained at Aorangi. The other is maintained at the AgResearch, Ballantrae Hill Country Research Farm as four replicated groups within the Low-Chemical Farming Systems Research Programme.

Line 4: A new line, selected for an index combining high resilience and low FEC, was established in 2000 using animals originating mainly from the Resilient lines. The Index line was established at Kaitoke and moved to Aorangi with the other lines in 2006. Replacement females for the Index line were bred from within that line, whilst rams were obtained from the best available from either the Resilient or Index line.

The Control line has been maintained for comparison with the above selection lines, by direct measurement of lines grazing together, or by the use of reference sires to provide common genetic links among lines across farms or years.

Management of selection lines

Management and selection procedures have been essentially the same from year to year. After mating in single-sire groups in April/May, pregnant ewes from all lines graze together. Lambs are identified to dam and tagged within 24 hours of birth. At weaning in December, at an average age of 12 weeks, the lambs are treated with an effective anthelmintic drench and split into separate ewe and ram lamb mobs.

Ewe lambs: All lines graze together from weaning onwards, on pasture previously contaminated with nematode parasites by sheep. Fresh faecal samples are collected routinely from a small random group, across all lines, in order to monitor FEC. When the mean FEC in the monitor group reaches approximately 1,500 eggs per gram (epg), in January/February, all lambs are faecal-sampled and their FEC measured (FEC1), weighed and scored for dags (0 = No dags, to 4 = Heavy dags). They are then treated again with an effective anthelmintic, referred to as the "FEC1 drench". This cycle is repeated, with a further period of exposure to a natural nematode challenge, followed by a second faecal sample (FEC2), dag score, and drench treatment in March/April. An autumn live weight is taken at about the same time as FEC2, and a yearling greasy fleece weight (YGFW) is recorded in September/October.

Ram lambs: Lambs from the Resistant, Resilient, Index and Control lines generally all graze together. Those from the latter three lines are drenched individually under a targeted selective drenching regime to assess their "drench requirements", reported here as "age at first drench". This involves regularly weighing all animals being tested for drench requirements, initially at fortnightly intervals in January, and then weekly from February onwards. Those with the lowest relative weight gains under specified conditions are selectively drenched with anthelmintic (Bisset *et al*., 2001; Morris *et al*. 2001, 2004). Faecal sampling for FEC1 is carried out on all lambs before the commencement of selective drenching, in order to avoid bias for the FEC1 comparison.

Data presented here are from the lamb crops born between 2000 and 2006, in environments where parasite challenge comprised predominantly *Trichostrongylus* sp. and *Teladorsagia* sp. The traits compared are live weight in December at weaning, in January and the "autumn" weights in March for the males and April for the females, as well as the corresponding gains from weaning to the January or autumn end-points, along with YGFW (females), FEC1, FEC2 (females), dag scores, and standardised age at first drench (StAge1) (males). A more detailed definition of StAge1 is given by Bisset *et al*. (2001).

Data analysis

The SAS JMP (1995) statistical package was used to compare lines for each trait, whilst making adjustments for significant fixed effects. Generally, these effects were line, year of birth, age of dam, sex of lamb (for weaning weight when sexes were grazed together), birth rank, date of birth as a covariate, and the interaction between line and year of birth.

RESULTS

Data from a total of 2,902 lambs were recorded. Table 1 shows the line comparisons and significance tests for all traits measured. The Resilient line had significantly higher live weights, weight gains and fleece weights, higher StAge1 and lower dag scores than the Control line, but did not differ significantly from the Control line in FEC1 or FEC2. Results indicate that, as anticipated for this selection line, the productivity and drench requirements were superior to the Control line, but there was no correlated selection response in FEC.

In the Resistant line, by contrast, the mean FEC1 and FEC2 values were 84% and 93% lower respectively than the Control line values. However, there was an associated production cost: lower weaning and autumn weight, and a lower YGFW and increased dag score compared with the Control line. Rams in the Resistant line were younger when they received their first drench than rams in the Resilient line by 0.87 SD ($P < 0.05$).

In the Index line, where the objective was to increase resilience and reduce FEC simultaneously, the responses in live weight and fleece weight were 3.5 to 6.8% superior to those expected in a cross between the Resistant and Resilient lines without the influence of heterosis. For example the March live weight was 23.6 kg for the Resistant line and 31.0 kg for the Resilient line to give an expected value of 27.3 kg for the Index line, whereas the actual weight for the Index line was 29.1 kg, equivalent to a 6.6% advantage. The mean dag scores in the Index line were lower than in the Control line, and StAge1was

Table 1: Least squares means of lamb performance traits in the Control, Index, Resistant and Resilient lines for sheep born between 2000 and 2006. For any trait (row), means in columns with differing superscripts differ significantly (P <0.05). Dag score: 0 = No dags to 4 = Heavy dags; StAge1 = standardised age at first drench, then transformed to standard deviation units; FEC = Faecal egg count, in eggs/g (Back transformed from $\log_e$ (FEC+100) transformation for analysis); FEC1 = January/February; FEC2 = March/April; RSD = Residual standard deviation.

Trait	Sex	Years of data	Control	Index	Resistant	Resilient	RSD
Number of animals	Ewe	7	412	236	383	449	
	Ram	7	401	202	357	462	
Weaning live weight (kg)	Both	7	19.7 ± 0.1^a	20.5 ± 0.2^b	18.0 ± 0.1^c	21.2 ± 0.1^d	2.9
January live weight (kg)	Ewe	7	22.6 ± 0.2^a	24.2 ± 0.2^b	20.6 ± 0.2^c	25.8 ± 0.1^d	3.0
	Ram	7	24.2 ± 0.2^a	25.8 ± 0.3^b	21.4 ± 0.2^c	27.0 ± 0.2^d	3.5
Liveweight gain, Weaning-January (kg)	Ewe	7	3.65 ± 0.08^a	4.38 ± 0.11^b	2.94 ± 0.09^c	5.25 ± 0.08^d	1.62
	Ram	7	3.34 ± 0.08^a	4.16 ± 0.11^b	2.28 ± 0.11^c	4.62 ± 0.08^d	1.59
April live weight (kg)	Ewe	7	24.9 ± 0.2^a	26.6 ± 0.2^b	22.9 ± 0.2^c	28.5 ± 0.2^d	3.0
Live weight gain, Weaning-April (kg)	Ewe	7	5.90 ± 0.11^a	6.73 ± 0.13^b	5.22 ± 0.11^c	7.91 ± 0.10^d	2.00
March live weight (kg)	Ram	2	26.4 ± 0.4^a	29.1 ± 0.6^b	23.6 ± 0.4^c	31.0 ± 0.3^d	3.8
Live weight gain, Weaning-March (kg)	Ram	2	5.26 ± 0.20^a	7.22 ± 0.32^b	4.66 ± 0.22^c	8.12 ± 0.18^d	2.09
Yearling greasy fleece weight (kg)	Ewe	4	2.15 ± 0.03^a	2.19 ± 0.04^{ab}	1.83 ± 0.03^c	2.27 ± 0.02^b	0.32
Dag score 1	Ewe	6	1.33 ± 0.06^a	0.87 ± 0.08^b	1.60 ± 0.06^c	0.59 ± 0.06^d	1.05
	Ram	4	1.33 ± 0.07^a	0.90 ± 0.10^b	1.50 ± 0.07^a	0.61 ± 0.06^c	0.99
Dag score 2	Ewe	7	1.54 ± 0.05^a	1.08 ± 0.07^b	1.67 ± 0.06^a	0.85 ± 0.05^c	1.02
StAge1	Ram	5[1]	-0.19 ± 0.05^a	0.04 ± 0.08^b	-0.59 ± 0.10^c	0.28 ± 0.05^d	0.85
FEC1 (epg)	Ewe	7	683^a	428^b	116^c	717^a	
	Ram	7	924^a	494^b	136^c	858^a	
FEC2 (epg)	Ewe	7	$1,170^a$	577^b	86^c	$1,175^a$	

[1] Data for all four lines were available for rams born in 2004 and 2005; Data for Control, Index and Resilient only were recorded for rams born in 2000, 2001 and 2006; No data recorded for rams born in 2002 and 2003.

higher (0.04 SD units) than the mean of the Resistant and Resilient lines (-0.16 SD units). Means for FEC1 and FEC2 in the Index line were higher, by 31 to 49%, than the expected cross-line $\log_e$ means of the Resistant and Resilient lines.

DISCUSSION

General

Before 2000 our work focused mainly on establishing experimental single-trait selected lines of nematode resistant or resilient sheep in order to study the genetic implications of these two selection strategies. It also provided a resource for further work directed at identifying genetic markers of the traits and understanding the mechanisms of host immunity to nematode infection in ruminants. However, for many years it has been clear that a combination of resistance and resilience would be necessary to optimise breeding programmes directed at reducing reliance on drench usage. Since 2000 our work has therefore included a search for a compromise between low-FEC selection, which leads to lower post-weaning gains and fleece weights, and high-resilience selection which in New Zealand has not been accompanied by any improvement in FEC.

Resistant and Resilient lines

Results for the Resistant and Resilient lines confirm that selection has achieved the direct responses anticipated. Mean FEC in the Resistant line was greatly reduced, by 84% to 93% of the Control line values. Direct selection in the Resilient line for improved resilience, that was intended to increase StAge1, has achieved this with a 0.47 SD unit advantage, equivalent to about 18 days over the Control line. This is broadly as predicted by Bisset *et al.*, 1994. Secondary correlated traits in the Resilient line which also improved were a reduction in dag scores, increased live weight, liveweight gain and fleece weight. In contrast, as also predicted in an earlier resilience paper (Bisset *et al.*, 1994), the FEC means in the Resilient and Control lines have been similar.

Index line combining Resistance and Resilience

In summary, the Index line had good growth and fleece weights, low dags, better StAge1 than expected, and poorer FEC values than expected. Combining desirable genes for Resistance and Resilience by index selection is a feasible breeding objective, as demonstrated in the Index line. However, while performance levels in the Index line were up to at least the expected cross-line averages in live weights and fleece weights, genetic progress in lowering FEC was diluted by simultaneous selection for resilience. At this stage it is not clear to what extent we can continue to lower FEC without compromising genetic progress in selecting for productivity in the face of nematode challenge.

The 3.5 to 6.8% live weight and fleece weight advantages above the cross-line average could variously have been the result of heterosis, selection intensities in the two parent selection lines being different over time, or the fact that more than half of the genes were derived from the more productive Resilient line. Heterosis has been reported as negative for FEC and positive for resilience, when this was measured as packed cell volume, in an American study with two breeds of lambs and their crosses (Li *et a*l., 2001). Age at first drench in the Index line was better than the expected cross-line mean by 0.20 SD units, although FEC means in the Index line were not as low as the corresponding cross-line average. Thus inbreeding, or loss of heterosis, within the unrelated Resistant and Resilient selection lines could explain the result for age at first drench in the Index line, but not the FEC result.

Although it is time-consuming for a ram breeder to record all the traits necessary to apply this form of index selection, we are aware of a small number of Romney breeders who now have the appropriate traits recorded to apply this selection (Morris *et al*., 2004). However, even if it is feasible to take the quantitative approach to breeding simultaneously for low FEC and high resilience traits, it is likely in the future that DNA markers will offer alternative genomic technology, to make improvements in resistance and resilience traits at the same time. Marker research has been under way for FEC in sheep for over 10 years (McEwan, 2007), with a thousand industry sires now progeny-tested and genotyped (Morris *et al*., 2007). Catapult Genetics Ltd is now offering a genomic testing service ('WormSTAR™') for New Zealand sheep which includes reduced FEC and increased post-weaning growth and overall productivity (http://www.catapultsystems.co.nz/products/55_wormstar.cfm; accessed 17 January 2008).

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