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Heritability of Johne's disease and survival data from Romney and Merino sheep

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ABSTRACT

Eight years of health records for ovine Johne's disease (OJD) from a long-term breeding trial with Romneys and Merinos at AgResearch's Tokanui Station were analysed, to study the quantitative genetics of animal resistance/susceptibility to OJD. Necropsy records were used in preference to serology to determine OJD status. A total of 2348 Romney and 1297 'Merino' ewe records (5 groups: two purebred Merino groups (Australian imported superfine and NZ purebred Merino), two Merino x Romney halfbred groups and a superfine Merino back-cross) were analysed for OJD and survival, comprising animals born between 1971 and 1978. Few males were retained past two years of age, so disease and survival data on males were excluded. Romney ewes had a mean lifetime incidence of OJD of 3.49% (range, by year of birth, 2.11 to 5.00%), whilst the mean for Merino ewes was 4.78% (range, by year of birth, 0.0 to 7.74%). The breed contrast approached significance ($P < 0.051$). The mean age at OJD incidence was 3.44 ± 0.09 years for Romneys, compared with a mean age for surviving females in the sample of 5.04 ± 0.02 years ($P < 0.001$). Corresponding means for Merinos were 3.38 ± 0.13 and 5.00 ± 0.04 years, respectively ($P < 0.001$). The heritability of lifetime incidence of OJD, considered as a binomial trait and using animal-model restricted maximum likelihood methods, was estimated as 0.07 ± 0.14 and 0.18 ± 0.11 for Romneys and Merinos respectively, giving an overall value (pooled within breeds) of 0.14 ± 0.09 . Adjusting for Merino group in the relationship matrix (rather than as a fixed effect) led to a heritability for Merinos of 0.24 ± 0.09 . These estimates may be biased upwards by 'vertical transmission' of OJD organisms from dam to offspring. The heritability of age at death/culling had values of 0.11 ± 0.04 and 0.16 ± 0.05 for Romneys and Merinos respectively, with a pooled value of 0.13 ± 0.03 . With the low heritability estimates for OJD in Romneys it is concluded that traditional breeding methods to reduce the incidence would be slow or unsuccessful; however, for Merinos, selection could begin to reduce the incidence, but ranking later generations may become difficult.

Keywords: Johne's disease; sheep; heritability; survival.

INTRODUCTION

Johne's disease affects domestic ruminant species including sheep, cattle, deer and goats, and it has an almost worldwide distribution. It is a chronic enteric disease caused by infection with the bacterium *Mycobacterium avium* subspecies *paratuberculosis* (West, 2002). In New Zealand the first case of ovine Johne's disease (OJD) was reported in 1952 in Canterbury, and the disease was first reported in North Island flocks in 1972 (West, 1997). Unconfirmed evidence suggests that the prevalence is higher in New Zealand in Merinos than in coarse-wooled breeds.

The present paper involves a long-term study of OJD from 1975 to 1982 at AgResearch's farm at Tokanui, Te Awamutu (formerly run by the Ministry of Agriculture & Fisheries). There were two flocks, Romneys and Merinos, which were both involved in long-term genetic selection trials to assess changes in production. Because of the apparent OJD incidence experienced in early years of the selection trials, intensive monitoring of OJD was undertaken. Diagnostic evidence of OJD was taken from *post mortem* analysis, in preference to serology. Survival ages and incidence of OJD have been summarised in the present analyses, and the results of breed and line comparisons and heritability estimates are reported here.

MATERIALS AND METHODS

Establishment and management of the flocks

Romneys. Selection and control lines of Romney ewes were established at Tokanui Station over the period 1970-

72, from stock assembled from 56 source farms across New Zealand and pooled first at Tokanui, Templeton (Christchurch) and Woodlands (Invercargill). The sources included commercial, pedigree and institutional flocks. Romney rams in the project were sampled from a total of 70 source farms (different from the ewe sources).

From the 1973 mating onwards, the ewes were permanently allocated to one of seven separate lines (*c.* 150 ewes mated per line per year). Four lines were randomly selected controls, two were single-trait selection lines (with selection for dam's lifetime lambing performance or yearling body weight), and there was a 'fertility index' line combining the two single traits. Further detail was given by Clarke & Johnson (1994).

Merinos. Two purebred Merino groups were established at Tokanui, beginning in 1970, namely a superfine Merino line based on an experimental importation in 1969 from Victoria and Tasmania, Australia (Carter, 1968/69; Dobbie *et al.*, 1985), and a New Zealand Merino line (of predominantly Peppin origin from South Island farms). From 1970 there were also two interbred groups (based on 50% Romney genes, and 50% NZ Merino or superfine Merino) and, from 1972, a back-cross line was added (where superfine Merino x Romney first-cross ewes were back-crossed with superfine Merino rams). After establishment, all animals remained within their breed/cross (approx. 125 ewes mated per breed/cross each year) and the breed/crosses were maintained until 1987. Selection each year was on yearling fleece weight, subject to a restriction on fleece type (originally by visual

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assessment; later using measured fibre diameter), with some attention also paid to yearling live weight. These five breed/crosses will be referred to here as the "Merino" resource.

Management. At all times, except for single-sire mating and the lambing to docking period, the Romney and Merino ewes grazed together. Both breeds of hoggets of the same sex also grazed together. For the first five years, five age groups of Romney ewes were routinely managed with culling-for-age at 6.4 years after weaning the fifth litter; in the three remaining years culling for age occurred at 5.4 years. In Merinos, the policy on culling age was less defined, with the majority of ewes being culled at 6.4 or 7.4 years of age, and a small number of purebred ewes (4%) retained to 8.4 years of age. Before these upper ages for culling ewes, there was generally no culling for poor production or other diseases, except as described below for signs of OJD.

Disease data collection

Few rams were retained past two years of age. Thus the opportunity to show the OJD phenotype was limited; any OJD deaths of rams were excluded from the present analyses. For ewes, those with low body condition or severe weight loss were blood-sampled for a serum OJD test (as a monitoring exercise only, because some false positives were identified), but any animals of two years of age and above which died were subjected to *post mortem* examination, and emaciated animals deemed to be unlikely to survive through the next season were euthanased for *post mortem* analysis. Animals which were confirmed positive to OJD by *post mortem* histopathology were classified as such in our data beginning in 1975 and continuing to the end of 1982, whilst the remainder of ewes were classified as OJD survivors. Numbers of ewes by breed and year of production are summarised in Table 1.

Data analyses

A contemporary group for each breed was defined to include animals grazing together. The traits analysed were: (i). age at disposal (when sold or culled-for-age if a survivor, or when died or euthanased if an OJD suspect). (ii). a binomial for fate: i.e., survived, or died from OJD. Means for age at disposal were calculated for all animals, and compared with those for the 3 to 5% of animals diagnosed with OJD. The heritabilities for both traits were obtained using animal-model restricted-maximum-likelihood (REML) procedures (Gilmour, 1997), with a full relationship matrix and a fixed effect for contemporary year group. In addition, a code for Merino breed/cross was tested in separate REML analyses, because preliminary data showed that there were significant breed/cross differences in incidence.

Because of the possibility of vertical transmission of OJD from dam to offspring via contaminated milk or faecal contamination on the udder (Valentin-Weigand & Goethe, 1999), additional analyses were carried out in three breed groups. In birth years 1971-74, there were NZ Merino x Romney, superfine Merino x Romney and Romney purebred animals, all born to similar Romney

ewes. Maternal breed effects, including possible vertical transmission, would be eliminated by comparing these three groups. Comparison of each halfbred group with Romney purebreds gives an estimate of the sire breed effect, but it is complicated by any effect of heterosis. Effects of maternal permanent environment and maternal genetic variance were also investigated by REML analysis.

RESULTS

Romney Line and Merino Breed/Cross Means

Table 1 shows the OJD incidence data for Romneys and Merinos, classified by years of production and of birth. The mean lifetime incidence of OJD was 3.49% for Romneys and 4.78% for Merinos and crossbreds, and the breed contrast approached significance ($P < 0.051$). The ranges by production year were from 0.66 to 2.20% in Romneys and from 0.26 to 2.90% in Merinos and crossbreds. Alternatively, re-classifying the data into birth-year groups, the ranges were from 2.11 to 5.00% in Romneys and from 0 to 7.74% in Merinos and crossbreds. Differences among the seven Romney lines were not statistically significant, in contrast to Merino breed/crosses in which the breed/cross means for lifetime incidence of OJD over all birth years were 11.3%, 5.6%, 5.5%, 2.9%, and 0.9% for the superfine purebred Merino, NZ purebred Merino, $3/4$ superfine Merino, NZ halfbred Merino and superfine halfbred Merino, respectively, which were significantly different ($P < 0.001$). Corresponding means for each Merino breed/cross per year of production were 3.28%, 1.71%, 1.82%, 0.97% and 0.29%, respectively.

The superfine halfbreds, NZ halfbreds and Romney ewes (all with similar Romney dams; 1971-74 birth years only) had means for lifetime clinical OJD of $0.7 \pm 0.7\%$, $3.9 \pm 2.2\%$ and $3.2 \pm 0.5\%$, respectively with, surprisingly, a significantly lower mean for the superfine halfbred than the Romney ($P < 0.05$).

For the 1973-76 birth years, it was possible to extract age-of-ewe effects, because all animals were recorded for OJD to at least 5.4 years of age. From 1160 Romney ewes, there were 1.33%, 1.51%, 1.28% and 0.25% OJD deaths in 2-, 3-, 4- and 5-year-olds. Corresponding values from 715 Merino and crossbred ewes were 1.14%, 2.44%, 1.84% and 0.24%. There were no significant differences among 2-, 3- and 4-year-olds within either breed. The trend was for lower death rates from OJD in 5-year-olds than in younger animals ($P < 0.01$ for Romneys; $P < 0.05$ for Merinos and crossbreds), with only two Romney cases and one Merino case of OJD from 5-year-olds.

Table 1 also shows the means for age at disposal, by breed of ewe and by clinical status. There were significant effects of status on age at disposal, for each breed, amounting to an overall difference of 1.61 years between survivors and ewes which succumbed to OJD ($P < 0.001$). Mean ages were surprisingly similar for the two breeds, in spite of different maximal ages at culling.

Heritabilities

Table 2 shows the heritability estimates for OJD incidence considered as a binomial trait, and for age at

TABLE 1: Number and percentage of ewes diagnosed with Johne's disease in Romney and Merino (and Merino cross) flocks at Tokanui Station, by production year and year of birth, and means of age at disposal.

Year of	Romney			Merino		
	Clinical cases	Total ewes	% Clinicals	Clinical cases	Total ewes	% Clinicals
Production						
1975	9	818	1.10	1	382	0.26
1976	7	976	0.72	4	502	0.80
1977	10	1083	0.92	5	577	0.87
1978	9	1042	0.86	15	655	2.29
1979	19	1085	1.75	8	633	1.26
1980	7	1053	0.66	9	632	1.42
1981	17	773	2.20	13	449	2.90
1982	4	474	0.84	7	250	2.80
All years	82	7304	1.12	62	4080	1.52
Birth						
1971	7	328	2.13	4	132	3.03
1972	7	230	3.04	0	93	0.00
1973	7	260	2.69	4	158	2.53
1974	15	300	5.00	11	180	6.11
1975	10	292	3.42	11	174	6.32
1976	15	309	4.85	10	206	4.85
1977	14	297	4.71	9	186	4.84
1978	7	332	2.11	13	168	7.74
All years	82	2348	3.49	62	1297	4.78
Disposal age(yr)	3.44±0.09	4.98±0.02 ^a		3.38±0.13	4.93±0.04 ^a	

^a Disposal ages of unaffected animals = 5.04 ± 0.02 years (Romney) and 5.00 ± 0.04 years (Merino).

TABLE 2: Heritabilities for Johne's disease incidence (analysed as a binomial trait) and age at disposal, estimated from Romneys, Merino purebreds, Merino crossbreds and all Merinos.

	Johne's disease incidence (0,1)		Age at disposal
	Year of birth, line ^a	Year of birth ^a	Year of birth, line ^a
Romney	0.07±0.14	0.07±0.14	0.11±0.04
Merino			
Purebred	0.11±0.05	0.14±0.14	0.28±0.10
Crossbred	0.16±0.23	0.21±0.21	0.00±0.00
All	0.18±0.11	0.24±0.09	0.16±0.05

^aFixed effects in the analysis.

disposal. The overall value for OJD incidence, pooled within breeds, was 0.14 ± 0.09 (not shown). The heritability estimates for OJD incidence were not significantly different when the line or breed/cross effects were excluded. These estimates may be biased upwards by 'vertical transmission' of OJD organisms from dam to offspring. However, no evidence of significant maternal genetic or maternal permanent environment effects were found, when the REML models were expanded to include these terms.

DISCUSSION

The breed difference in OJD lifetime incidence approached significance, as indicated by the Romney versus Merino breed/cross data in Table 1, and also by the contrast of halfbreds versus purebreds within the Merino resource. Relative to the average OJD incidence per lifetime for the two purebred Merino groups of (11.3 + 5.6%)/2 or 8.45%, the incidence in Romneys was about a half. The halfbreds had means for lifetime OJD incidence which were similar to, or less than, the Romney

mean, but there was insufficient flexibility in the data to separate heterosis from vertical transmission.

It would be difficult to design a heritability study of OJD where vertical transmission could be clearly disentangled from genetic factors. Cross-fostering from birth (or other means of completely separating dam from offspring) would probably be required, which is not practical with the large numbers required to estimate a heritability with small standard error.

The disposal ages for OJD clinical cases were 3.44 and 3.38 years for Romneys and Merinos, respectively, and the corresponding ages for survivors were 5.04 and 5.00 years, respectively, giving 4.98 and 4.93 years overall. In spite of the significant differences in disposal age between clinical cases and survivors, this had only a small impact on the overall means because there were only 3 to 5% of clinical cases. Means for OJD incidence are usually quoted per annum, but it is probably more useful to quote per 'lifetime' as in Table 1 (second panel).

Incidences in Australian Merinos were quoted by Abbott (2002) as 14.6% per annum, which is much higher

than the values found for Merinos here (1.52% per annum from our complete Merino resource or 3.28% per annum for the superfine Merinos only).

There was a suggestion of a difference in heritability of OJD incidence between Romneys and Merinos, but numbers of animals were too small (or trait means were too low) for this to be significant.

The heritability for age at disposal reflects the genetic variation for the overall disposal trait (regardless of cause). Some of these causes (culling for age, to avoid increases in flock size) are quite arbitrary. However there were insufficient animals to estimate heritability with low s.e. if "age at OJD incidence" was the analysed trait.

Based on the incidences and heritabilities in each breed, traditional breeding methods to reduce or eliminate OJD would probably be slow or unsuccessful in Romneys. Initial selection in Merinos could be more effective than in Romneys, but subsequent selection may then be hampered as in the Romney situation. In practice, decisions on rams would be the critical part of the selection process, and their ranking would need to be done using breeding values. Initially the data would come predominantly from information on dams and aunts, but paternal half-sisters and half-brothers would also be included if candidate rams were retained to four or five years of age. However, it would be difficult to keep the generation interval low. The disease is characterised as being of low incidence, late onset and, if rams are routinely culled/sold young, also sex-limited in practice. It is a disease where access to OJD-gene markers, or to closely linked markers, could provide easier routes to breeding for resistance.

In conclusion, ovine Johne's disease was studied in 3645 ewes on one property over eight years. Merinos had a higher incidence than Romneys, amounting to a factor of approximately two in purebreds. Heritabilities were 0.07 for Romneys and 0.18 for Merinos and their crosses. The average age at disposal of ewes was 1.61 years younger in *post mortem*-confirmed OJD cases than in survivors. Breeding for greater resistance using traditional selection means would be very slow in Romneys. In Merinos and crossbreds, this approach could be successful in early generations, but progress rates would probably decline over time. A gene marker test would be of great assistance.

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