ULTIMATE DISEASE RESISTANCE IN SHEEP: WHAT ARE THE RELATIONSHIPS BETWEEN ALL MAJOR DISEASES?

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SUMMARY

A study is described which is unique in that resistance to each of the major diseases which affect production in Merino sheep was measured in the same flock under the same environmental conditions. Results indicated that within the one flock, genetic variation exists for resistance to internal parasites, footrot, fleece rot and dermatophilosis. Heritability estimates were similar to those published from separate resource flocks. Results also showed that genes conferring resistance to one disease do not, in general, have any effect on resistance to other diseases. The exceptions to this general rule are that resistance to internal parasites and dermatophilosis have some genes in common (a positive association), as do resistance to fleece rot and footrot (a negative association). Practical implications for industry to develop Merino strains with 'broad based' disease resistance are discussed.

Keywords: Merino, disease resistance, internal parasites, footrot, fleece rot, dermatophilosis.

INTRODUCTION

For most sheep production systems, internal and external parasitism remain high on the priority list for sheep managers to deal with. Although a wide range of chemical and management tools can be used to alleviate the threat of parasites, concerns about chemical residues, resistance to most chemicals developed for parasite control, and recurrent costs of such treatments require alternative and complementary control approaches. One such approach includes exploitation of genetic variation in resistance by the host to parasitism. Similar approaches have been considered for the major infectious diseases, although the urgency for alternative control systems is less, given access to suitable vaccines, and effective drug therapy.

This paper examines what levels of genetic variation in resistance to each disease can be expected; whether it is possible to have genes for resistance to each of the major diseases present within the same flock; to what extent resistance to the important diseases has genes in common; and whether there are antagonistic genetic relationships between resistance to different diseases.

GENETIC VARIATION IN DISEASE RESISTANCE - THE OVERALL PICTURE

Aspects of disease resistance in sheep have recently been reviewed by Gray *et al.*(1995) and Raadsma *et al.* (1997).The primary focus has been on resistance to internal parasites, footrot, and blowfly strike; and to the latter's major predisposing dermatoses, namely fleece rot and dermatophilosis. From the many studies conducted so far, we can conclude that genes affect the expression of resistance to each of the major diseases which affect production in sheep.

Unfortunately, most of the relevant studies have examined only one of the specific diseases in research flocks where genetic factors could be disentangled from the numerous environmental factors which affect disease expression. The question then remains - is it likely that genetic resistance to all these diseases is present in animals in the same flock; and if so, do the same animals carry genes which make them resistant to more than one disease? To answer these question, it is necessary to have a flock suitable for genetic analysis and in which all the relevant diseases are measured. One such resource has been managed by the Centre for Sheep Research and Extension at the University of Sydney , Camden, specifically for genetic investigations of disease resistance in sheep.

CAMDEN RESOURCE FLOCK

The structure of this Merino flock and the research objectives have been detailed by Raadsma and Nicholas (1993). The flock consisted of 1200 Merino ewes from four different bloodlines representing three medium-wool and one superfine-wool flocks. Rams and ewes were selected at random, and mated in single-sire groups of approximately 30 ewes. A total of 3200 progeny from 162 such sire groups were intensively studied for a wide range of disease and production characteristics. Disease traits included resistance to internal parasites, as reported by Eady *et al.* (1996), footrot as reported by Raadsma *et al.* (1993), dermatophilosis as reported by Raadsma *et al.* (1992), and fleece rot as reported by Raadsma *et al.* (1988). This represents a unique situation where all the major diseases which affect Merino sheep have been measured in the same resource flock, born and raised in the one environment.

For each of the diseases, genetic differences between individuals contributed to the variation in disease expressed in the flock. Heritability estimates for faecal egg count (FEC) following natural challenge with predominantly *H contortus* and *T colubriformis* was 0.19. Resistance to footrot following challenge with a virulent isolate of *D nodosus* had a heritability of 0.29. Fleece rot was measured at 10, 16 and 22 months, and between 27% and 41% of the total variation was under genetic control. For resistance to *D congolensis* infection, 23% of the observed variation was due to genetic differences between individuals. In other words, genetic variation was observed for all disease traits examined, and estimates are in line with those published to date.

GENETIC RELATIONSHIPS BETWEEN RESISTANCE TO THE VARIOUS DISEASES

The degree to which genes for resistance to one disease are 'shared' with genes for resistance to other diseases can be conveniently expressed as the co-heritability, expressed as $r_g.h_1.h_2$, for any combination of disease traits, where r_g represents the observed genetic correlation between the two traits, and h_1 and h_2 are the square roots of the respective heritability estimates. It is useful to compare actual estimates with the maximum degree of genetic control which can be shared for any two traits, namely those with a genetic correlation of unity. A positive co-heritability indicates that resistance to one disease has a positive effect on resistance to another disease. Conversely, a negative co-heritability indicates an undesirable effect on resistance to another disease. From the observed co-heritability estimates, we can make verbal predictions of the likely effect of selection for resistance to one disease on resistance to the other important diseases. These are shown in Table 1.

In the case of resistance to internal parasites, it can be seen that there is little genetic variance in common with resistance to fleece rot and footrot. In other words, selection for increased resistance to internal parasites will have no effect on resistance to fleece rot or footrot, and vice-versa. The moderate positive co-heritability between resistance to internal parasites and resistance to dermatophilosis is similar to the relationship observed by Woolaston *et al.* (1995) for a Merino resource flock in South Australia, but in contrast to findings by the same authors for a similar resource flock in Western Australia. On balance, the data suggest a positive genetic relationship between resistance to these two diseases, but this will need to be investigated further.

Resistance to footrot appears to have no common genetic ground with resistance to any of the other important diseases (Table 1). Similar findings can be seen for resistance to dermatophilosis, with the possible exception of the co-expression of resistance to internal parasites, as discussed above.

Resistance to fleece rot appears to have no genes in common with resistance to either dermatophilosis or internal parasites. However, a slightly undesirable relationship exists with resistance to footrot, suggesting improvement in resistance to fleece rot may lead to a small decrease in resistance to footrot (Table 1).

Table 1. Predicted changes in diseases resistance following selection for any of the major diseases in sheep

Selection for increased resistance to:	Predicted correlated changes in resistance to:			
	Internal parasites	Footrot	Fleece rot	Dermatophilosis
Internal parasites	-	slight increase	no change	slight increase
Footrot	slight increase	-	slight decrease	no change
Fleece rot	no change	slight decrease	-	no change
Dermatophilosis	slight increase	no change	no change	-

CONCLUSIONS FROM THE CAMDEN STUDY

The study described here is unique in that a range of diseases have been measured on sheep in the same resource flock and under the same environmental conditions. Results show that within the one flock, genes are present which confer resistance to each major disease of interest to sheep breeders. Heritability estimates are similar to published estimates derived from separate studies in other resource flocks. Results show also that, in general, resistance to each of the major diseases is an independent trait - that genes conferring resistance to one disease do not, in general, have any effect on resistance to other diseases. The exceptions to this general rule are that resistance to internal parasites and to dermatophilosis appear to have some genes in common; as do resistance to fleece rot and to footrot. These results have important practical implications. The major implication is that genetic change in resistance to any of the major diseases will, in general, have no marked effect on resistance to other diseases. Conversely, development of programmes aimed at 'broad based' disease resistance will need to consider each relevant disease; it will not be possible to achieve correlated response in resistance to one disease by selecting for resistance to another disease. In other words, there is no 'universal' set of genes that enhance resistance to all major diseases. This complicates the inclusion of disease resistance in breeding programmes. If all diseases are considered simultaneously in a breeding programme, progress in improving resistance could be slow and costly. However, it should be possible to readily combine genes for resistance to various diseases from different flocks which have been selected for resistance to just one disease. This type of breeding exercise would be greatly assisted by gene markers.

IMPLICATIONS FOR INDUSTRY

From an industry perspective, the concept of broad-based resistance is important, given that the major diseases highlighted here have common environmental conditions as precursors to their expression: high rainfall and moderate temperatures and improved pasture grazing conditions tend to favour the development of the parasitic and skin diseases for which we have some information on the scope for genetic improvement. There is already considerable interest by Merino sheep breeders in resistance to fleece rot and internal parasites. Information from sire-reference schemes confirms considerable genetic differences between sires in their genetic predisposition to disease (Eady 1995; Cottle 1996). Similar information is not yet available for resistance to footrot and dermatophilosis, but could and should be available in the future.

The implications for sheep breeders are that documented information is now available, or could be made available, to choose sires which may give a rapid lead to improve resistance to a specific disease. Merino breeders have the added option of choosing sheep from a foundation of resistant bloodlines. This is possible for resistance to fleece rot where highly resistant bloodlines are already available in industry flocks. Similar differences do not exist for resistance to internal parasites (Eady *et al.* 1996) but may exist for resistance to dermatophilosis and possibly footrot (Raadsma, Swan and Purvis, unpublished), although the latter is not documented in commercial bloodline comparisons. The options to the breeder could then extend to combine resistant bloodlines for a number of traits and then use the combined flock to develop an improved bloodline with enhanced disease resistance.

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