USING ASSORTATIVE MATINGS TO MAXIMISE SALES OF HOMOZYGOUS FAVOURABLE SHEEP SIRES, A SIMULATION STUDY

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SUMMARY
A stochastic simulation model of a sheep breeding program is used to show how assortative matings can increase the number of rams sold which are homozygous favourable for a major gene. The commercial implications of such a strategy are discussed in comparison with strategies focused more on increasing gene frequency. Long term inbreeding is unaffected while the lost response to selection for polygenic merit is substantially reduced, when homozygosity is increased through assortative mating, rather than though increasing the gene frequency in the population and using random mating.

INTRODUCTION
Rapid advances in molecular biology, in terms of both cost, and capability of downstream technologies, mean that marker assisted selection breeding programmes are becoming increasingly attractive to sheep breeders. However such programmes may be costly and will only deliver increased overall genetic gain if managed well, particularly as the individual quantitative trait loci (QTL) for which markers are becoming available are often modest in their effects on total economic merit. Thus, careful and innovative consideration is required when integrating information from QTL markers into a commercial breeding programme.

One innovative way for reducing the cost of marker assisted selection is to integrate gene and marker tests with wide scale identification of lamb parentage through DNA markers. Low cost DNA marker strategies were described by Sise et al. (2001), and these are becoming increasingly popular among New Zealand sheep breeders, particularly those of large and very large scale. In this way, the marginal cost of testing for QTLs in animals already tested for DNA parentage is minimal. DNA testing of the full population for QTL markers opens up opportunities for planned matings based on genotype.

Genetic tests for two QTL affecting carcase quality are under preliminary evaluation in New Zealand (Broad et al. 2000, Jopson et al. 2001). While the primary value of these tests is to increase carcase value overall, a key secondary goal is to increase consistency of carcases presented to a processor. In order to provide a premium processors may demand uniformity of genotype effects within a batch of lambs being slaughtered together, perhaps to a specific cutting specification. As a consequence, a team of homozygous favourable rams for a QTL with additive or dominant expression sourced from a terminal sire breeding programme might be substantially more valuable than both non carrier and heterozygous rams. This is because all of their progeny will be guaranteed to be at least carriers.
The objective of this paper was to compare selection and mating strategies with and without assortative mating in relation to the number of rams for sale that are homozygous favourable for a QTL and where QTL genotype is known for all selection candidates. The strategies are also compared in terms of their implications for gene frequency, inbreeding, and polygenic merit for traits unaffected by the major gene.

MATERIALS AND METHODS

The simulation model used for this study is described in more detail by Sherlock et al. (2005). In brief, births of individual animals are simulated along with their performance records for traits of interest in New Zealand sheep breeding programmes. Alternative selection and mate allocation rules can be implemented for these animals, with alternative trait indexes able to be applied for selection of different stock classes (e.g. ewes and rams) and to apply assortative mating rules. The mating system also uses linear programming techniques to assign assortative mating systems subject to constraints on the resulting inbreeding coefficients for progeny.

In this study, animals were simulated in a single flock breeding terminal sire rams for sale and comprising 1000 breeding ewes mated of which .35, .3, .25 and .1 were 2, 3, 4, and 5 years of age respectively. The QTL simulated was biallelic with a starting frequency of 0.1 and assumed to have no phenotypic effect on conventional selection criteria including a genetic merit index based on estimated breeding values, and a separate breeder preference trait. The same selection criteria was applied in sire, replacement ewe and cull ewe selection decisions, by selecting on a merit index with equal emphasis given to breeder preference phenotype and estimated breeding values for liveweight at 8 months of age, simulated by combining simulated true breeding values for liveweight at 8 months with uncorrelated prediction errors. Additional selection emphasis was applied based on QTL genotype, by increasing the merit index by 2.5 (high rate of fixation), 0.25 (moderate rate of fixation) and 0 standard deviations of the merit index prior to adjustment for QTLs for each copy of the allele carried by the selection candidate. Each year, 10 ram lambs were selected for mating to ewes. Mate pairs were assigned using linear programming to avoid inbreeding coefficients greater than 0.025 in progeny, and depending on the situation, using no positive assortment bias based on the merit index, and alternatively, using a strong positive assortment bias (still avoiding inbreeding). Each system was replicated 4 times with different starting seeds, so as to remove some of the random errors implicitly associated with stochastic simulation.

RESULTS

Results are shown in Figure 1 with separate lines plotted for three levels of selection emphasis on the QTL and both with and without positive assortative mate allocation. For high and zero levels of selection emphasis on the favourable QTL allele, the positive assortative mating had minimal impact on results. This is because all of the rams selected were of high merit. With the moderate degree of emphasis on the QTL, the positive assortment mate allocation resulted in a substantial acceleration in the rate of increase of homozygous favourable lambs born. This is because the positive assortment
Figure 1. Effects of alternative amounts of selection emphasis placed on a favourable QTL allele with and without positive assortative (best to best or B2B) mate allocation in a 1000 ewe terminal sire flock. First selection under each strategy started for the 2000 mating.

allocation results in more carrier rams being mated to carrier ewes than otherwise. Having a very high level of emphasis on the major gene resulted in a more rapid rate of fixation for the favourable allele, but genetic progress for growth rate appears to have been moderately compromised to the extent that
animals under this selection system were approximately 1.5 kg lighter at the same age after 5 years of selection with high emphasis on the QTL, relative to zero emphasis. This equates to approximately 3 years of genetic progress.

DISCUSSION
The results of this study identify the potential value of positive assortative mating systems to bring about more rapid increases in the number of animals for sale which are homozygous favourable, with only relatively modest selection emphasis to increase QTL gene frequency. There are well established advantages of reducing the rate of increase in gene frequency of specific QTLs in terms of reducing the loss of genetic progress for polygenic merit (Gibson, 1994), and evidence of these advantages has been further demonstrated here.

There are some additional potential advantages from reducing the rate of increase in gene frequency, and instead using assortative mating to increase the number of homozygous favourable offspring born. Where the full consequences of a QTL across all commercially relevant production characteristics are not yet well understood, sufficient numbers of animals of favourable genotypes will be generated quite rapidly, with an easier path back to lower gene frequency remaining if some deleterious consequences are associated with the QTL. Furthermore, only a subset of the ram buying clientele of the breeder may be in a position to capture benefits. This is particularly so for carcase genes where the value has to be captured through procurement premiums, rather than through a standard carcase payment schedule. In this instance, maintenance of high rates of genetic progress in conventional genetic merit will be essential if the ram breeder is to maintain market share.

While the selection systems with the high rates of increase in QTL gene frequency appear to have less inbreeding, this may be an artefact due to animals being assumed to be unrelated at the start of the simulation. Related simulation studies, but where the QTL is introgressed from another flock that is slightly inferior for average genetic merit, showed the opposite effect (results not shown).

REFERENCES