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Impact of breeding technologies on the genetic gain of a Merino flock

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ABSTRACT

Several breeding technologies are available to sheep breeders for increasing the rate of genetic progress in their flocks. The relative merits of these technologies depends on the selection objective and other breeding and management circumstances. This paper investigates the effects of artificial insemination (AI), progeny testing and an open-nucleus flock, on a breeding programme for fine woolled merinos. The selection objective was to decrease Mean Fibre Diameter (MFD) while maintaining Clean Fleeceweight (CFW).

Two population structures were considered:

a) Maintaining a closed nucleus flock of 1000 breeding ewes

b) Operating an open-nucleus breeding scheme sourcing a proportion of replacements from the progeny of 5000 contributing ewes.

For each structure, the benefits of AI and progeny testing were investigated individually and in combination.

For the range of options considered, selection resulted in a reduction of one micron in MFD every three to five years, with no reduction in CFW.

All other things equal progeny testing decreased the genetic progress possible by 0.04-0.06 μ/year. An open-nucleus breeding scheme increased the rate of genetic gain by 0.06 μ/year with progeny testing or 0.03 μ/year in the absence of progeny testing. AI increased genetic progress by 0.06 μ/year.

The combination of AI and an open nucleus provided the maximum potential rate of genetic gain (0.36 μ/year). To optimise the age structure for this combination of breeding technologies, the nucleus flock comprised 60% two-tooth ewes.

These results describe the impact of breeding technologies on the rate of genetic gain. To determine their cost-effectiveness, the marginal genetic gain provided by any individual technology must be weighed up against the costs and management constraints that the technology imposes.

Keywords: genetic gain; new technology; evaluation; AI; progeny testing.

INTRODUCTION

Breeding technologies such as artificial insemination (AI) and multiple ovulation and embryo transfer (MOET) are increasingly available to sheep breeders. Technologies such as semen sexing and DNA-based techniques will be available in the future. Breeders need to assess the benefits of these technologies for their situation before deciding whether to implement them. These technologies generally benefit the breeder by increasing the rate of genetic progress. However, new technologies will impose direct costs associated with testing and equipment purchases and their introduction usually impacts on management complexity and flexibility. It is difficult to evaluate these management costs, but in general if a technology requires complex management systems it is more likely to fail in practise, and if two technologies generate the same genetic progress the one requiring the least management inputs will be the more desirable.

To carry out on-farm evaluation of a technology is expensive in terms of time and resources. Simulation models offer a fast inexpensive method for assessing new technologies.

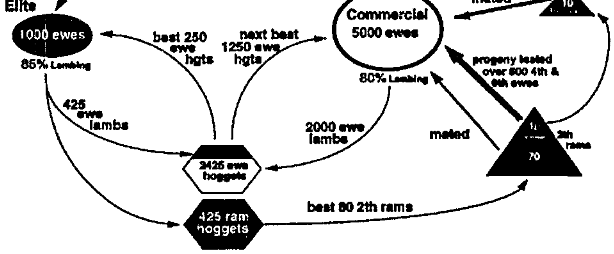
This paper uses simulation techniques to evaluate the impact of three currently available breeding technologies on the genetic gain in a fine woolled Merino flock

1. Screening of "commercial" hoggets into an elite flock (Open-nucleus).
2. Progeny testing of two-tooth rams bred in the elite flock (Progeny testing)
3. Artificial insemination of progeny-tested sires over elite ewes. (AI)

MATERIALS AND METHODS

A model which simulated the distributions of genetic merit within source flock, sex, year and age, was built to evaluate each combination of the three technologies using the APL language (Michelson and Kierman, 1982). Selection decisions were based on a breeding objective to reduce MFD while holding CFW constant. Figure 1 illustrates the breeding

FIGURE 1: Breeding strategy incorporating an open nucleus, artificial insemination and progeny testing.



strategy that incorporated all three of the technologies.

Elite and Commercial ewe lambs were run together from weaning until selection of replacements at 12 months of age when each hogget had one record available for mean fibre diameter (MFD), yield, greasy fleeceweight (GFW) and clean fleeceweight (CFW). The best 250 ewe hoggets were chosen to become replacements for the Elite flock. The next best 1250 ewe hoggets entered the Commercial flock.

Only ram lambs born in the Elite flock were eligible to be used as sires. All ram lambs were kept until eighteen months of age at which time the best 80 two-tooth rams were chosen using an 18 month MFD record in addition to previous hogget information. The best 10 of these 80 was mated (progeny tested) to a random selection of 500 four-tooth and six-tooth ewes from the Commercial flock. The remaining 70 two-tooth rams were mated to the rest of the Commercial ewes. The result of the progeny test was not available until the rams were forty-two months old. At that time the best three rams were chosen to be mated via AI (as six-tooth rams) to ewes in the Elite flock.

The effects that each of the technologies had on the breeding strategy are shown in Table 1.

TABLE 1: Management impact of technologies on the breeding strategy.

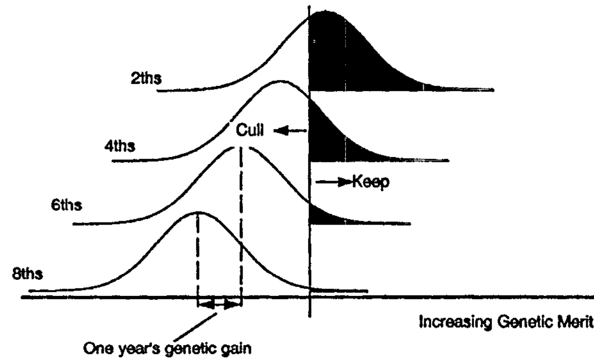
New Technology	Control
Open Nucleus	*Closed Nucleus*
Ewes born in the Commerical flocks are also eligible to become parents in the Elite flock	Only ewes born in the Elite flock are eligible to become parents in the flock
AI	*Natural Mating*
3 rams are mated to the Elite flock via AI	20 rams are naturally mated to the Elite flock
Progeny Test	*Individual Selection*
The best six-tooth rams are mated to the Elite flock	The best rams are mated to the Elite flock, regardless of age

The genetic parameters (heritabilities, genetic correlations, phenotypic variances) required to estimate the rate of progress towards the objective, were obtained from the analysis of an Otago Merino flock consisting of 10,000 breeding ewes, recorded over 10 years. Relative economic values (REVs) were calculated using SELIND (Cunningham and Mahon, 1977) such that a reduction in MFD was achieved with no change in CFW (REV for MFD = -3 units/μ, REV for CFW = 1 unit/kg).

When progeny testing was not used sires were the highest merit rams across all age groups. An adjustment was made to take into account the reduction in variance resulting from the two-stage selection of the progeny tested rams (Cochrane as cited by Dickerson and Hazel, 1944). The number of hogget replacements for the first round of selection is shown in Figure 1. For subsequent rounds of selection, the required number of dams were chosen from the highest merit ewes across age groups as illustrated in Figure 2. Figure 2 shows that the optimal flock composition contains a large proportion of younger animals, because they are of higher merit than older animals.

The models assumed that the initial flock was unselected. Top ranking animals across ages were selected to parent the next generation within the constraints of each particular breeding strategy. This process was iterated until the annual rate of genetic gain stabilised (Ducrocq and Quaas, 1988). This equilibrium rate of genetic gain was used as a measure of the potential rate of gain for that particular combination of breeding technologies.

FIGURE 2: Selection of highest merit replacements across ages.



RESULTS

Table 2 shows the equilibrium rates of genetic gain for each combination of technologies. Rates ranged from 0.21 to 0.36 μ/year indicating that it is possible to reduce MFD by one micron every three to five years, without diminishing CFW. The maximum potential rate of genetic gain (0.36μ/year) was achieved in an open nucleus, using AI from sires selected on ancestral and individual performance.

Strategies including progeny testing of sires had a 0.04 to 0.06 μ/year lower rate of potential genetic progress than the same strategies with sires selected at a younger age using ancestral and individual performance but no progeny records.

The inclusion of an open nucleus in a mix of technologies that also included progeny testing increased the rate of genetic gain by 0.06 μ/year. In the absence of progeny testing an open nucleus increased genetic progress by 0.03 μ/year.

AI increased genetic progress by 0.06 μ/year.

DISCUSSION

A comparison of the various systems is shown in Table 2. Both open nucleus and AI technologies have a positive

TABLE 2: Impact of Breeding technologies on Genetic Progress (μ/yr).

Open Nucleus	AI	Progeny Test	Potential Genetic Progress[1]
✓	✓	✓	0.32
✓	✓		0.36
✓		✓	0.27
✓			0.30
	✓	✓	0.27
	✓		0.33
		✓	0.21
	Control[2]		0.27

1) The breeding objective effectively held CFW constant while decreasing MFD. Genetic progress can therefore be measured in microns/yr.
2) Closed flock, natural mating, sires selected on ancestral and individual information.

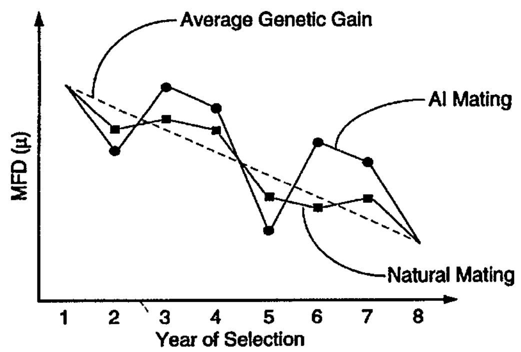
effect on genetic progress, whereas progeny testing decreases genetic progress.

Although progeny testing predicts an animal's true merit more accurately than individual observation, the time required before an animal can be used as an Elite sire slows down the turnover of genes between generations. In cases where the heritability of a trait is low (<25%), or where a trait can only be measured in one sex (e.g. milk yield), the advantages of progeny testing usually outweigh the disadvantages. However for traits such as CFW and MFD, which are highly heritable (Turner and Young, 1969) and can be measured in both sexes, measurements on the animal itself are an accurate indication of the animal's genetic merit.

An open nucleus increases genetic progress by increasing the number of animals available for selection and therefore increasing the intensity of selection. The advantage of an open nucleus over a closed nucleus is greater if sires are progeny tested (0.06 vs 0.03 /yr), because the offspring from the progeny test matings can be screened into the Elite flock. The disadvantages of an open nucleus relate mainly to management considerations, particularly the time and cost of measuring extra animals. These factors must be weighed up against the marginal 0.03 micron gain per year to determine whether maintaining an open flock results in a net benefit or a net cost.

Artificial insemination produced the greatest increase in annual genetic progress. AI (like open-nucleus screening) achieves its increase by increasing the intensity of selection, but it does so by decreasing the number of animals selected, rather than by increasing the number available for selection. Because each sire will have more offspring when AI is used, each sire will have more influence on the flock as a whole. This means that although the average genetic gain will remain constant, fluctuations from the mean rate of gain will be amplified relative to natural mating (Figure 3). Also, if a sire carries undesirable genes (e.g. susceptibility to footrot or fleece pigmentation genes) and is mated via AI to many ewes, more of the flock will be affected.

FIGURE 3: Stylised fluctuations in the rate of genetic progress for natural mating and artificial insemination (AI).



The appreciable increase in selection intensity achieved using AI may be possible through less costly and labour intensive means. Ram:Ewe ratios assumed for natural mating were about 1:50 compared to 1:300 for AI. Satisfactory conception rates from natural mating can be achieved at Ram:Ewe ratios of 1:250 (Allison, 1975), given the right mating conditions. If merino breeders are able to provide small, easy contoured paddocks suitable for low mating ratios they could decrease annual breeding costs substantially, with very little loss of genetic gain relative to using AI.

CONCLUSIONS

Progeny testing is not an appropriate breeding technology for objectives based on fleeceweight and fibre diameter in fine-woolled Merino flocks, because it introduces financial and management costs with no associated benefit in genetic progress.

An open nucleus is most beneficial when progeny testing is also used. In the absence of progeny testing, it is doubtful whether the costs associated with an open nucleus outweigh the benefits.

AI has the largest impact on genetic gain, but much of this impact could be achieved, at lower cost, by decreasing the ram to ewe ratio commonly used for natural mating.

This paper has considered the impact of three breeding technologies on the rate of genetic gain. Before farmers are able to make an informed decision on whether to implement a technology on farm, the management and financial implications of these technologies should also be considered.

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