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Dynamic selection for sheep genetic improvement

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ABSTRACT

Dynamic selection is a process used in livestock improvement programmes to maximise genetic progress while constraining the long term rate of inbreeding. An optimisation algorithm identifies proportions of genes each selection candidate should contribute to the next generation. Application of dynamic selection procedures to select cull and replacement ewes, and then subsequently to select a ram team, was demonstrated using data from a Romney sheep breeder. When compared with selection based on an index of breeding values alone, dynamic selection of cull and replacement ewes reduced the accumulation of relatedness by approximately 85% of the average annual accumulation from 1994 to 2000. To achieve this, approximately 33% of the average annual genetic progress in average index value was sacrificed. Using dynamic selection to identify a ram team to be mated to selected ewes resulted in a saving in relatedness by an amount equal to the average annual accumulation from 1994 to 2000 with only a very modest drop in genetic progress of 9% of the average annual genetic progress in average index value. This study has demonstrated that dynamic selection tools could, when practically applied to sheep breeding populations, provide a transparent and efficient means of managing the tradeoff between rate of genetic progress and rate of accumulation of relatedness.

Keywords: Dynamic selection; inbreeding; sheep; genetic response.

INTRODUCTION

Dynamic selection involves choice of genetic contributions of selection candidates to the next generation with the objective of maximising the genetic progress achieved from the current selections subject to a constraint on the rate of inbreeding. The application has been previously described in these proceedings for a theoretical population with a segregating major gene (Amer & Villanueva, 2000) and also within a salmon breeding programme (Amer *et al.* 2001). Avendano *et al.* (2002) have investigated the application of dynamic selection to sheep in the UK. A method that simultaneously applies dynamic selection principles and allocation of mating pairs is available to sheep breeders in Australia (Kinghorn & Shepherd, 1999).

When applying dynamic selection, alternative combinations of selected parents, and the degree of each parent's genetic contribution to the next generation are compared until the combination that maximises the rate of genetic progress subject to a constraint on the rate of inbreeding is found. An efficient searching algorithm to find the optimum combination has been described by Meuwissen (1997).

Practical implementation of dynamic selection in commercial sheep populations requires maximum and minimum constraints on the genetic contributions of individuals. For example, a single ewe can not be expected to be the mother of 30% of lambs born in a 500-ewe flock without implementation of reproductive technologies that may not be cost-effective. Similarly, mating groups of very small numbers of ewes to a number of rams will also be impractical in many situations. However, recent developments in the optimisation methods and their availability through licensed computer software (T. Meuwissen, unpublished) mean that the required constraints can be implemented, and thus, dynamic selection has now been made available as a tool for New Zealand sheep breeders.

The objective of this paper is to demonstrate the application and benefits of dynamic selection when applied to a large commercial Romney breeding population.

MATERIALS AND METHODS

Animals and data

Data from the Awareka flock owned by Murray Rohloff in Southland were used in this study. Records available included pedigree information for animals born from 1989 onwards, and index values computed using Best Linear Unbiased Prediction (BLUP) using the Sheep Improvement Limited (SIL) national genetic evaluation system (Newman *et al.* 2000). There were approximately 1800 recorded ewes lambing each year and between 2300 and 3600 lambs born each year. Average sire age ranged between 1.8 and 3.1 years while average dam age ranged between 3.4 and 4.1 years. Between 1994 and 2000, the observed rates of inbreeding, and the average coefficient of relationship among parents, increased by an average of 0.40 and 0.90 % per annum respectively. The coefficient of relationship gives the increase in the probability that two genes are the same for two individuals when the two are related over that of two unrelated individuals. The inbreeding expected with random mating of parents is equal to one half of the average coefficient of relationship among parents, so the expected inbreeding of 0.45% (one half of the 0.90% average of coefficients of relationship) is slightly higher than was actually achieved. Over the same period, annual genetic improvement in SIL dual-purpose selection-index values (Amer, 2000) increased by an average of \$0.72 per annum in this flock. These rates of inbreeding and genetic improvement occurred in the absence of application of dynamic selection tools.

Computer software

The computer programme called GENCONT, available from T. Meuwissen (unpublished), was used for

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dynamic selection. GENCONT has several characteristics that make it practical for application to sheep improvement programmes, including the ability to assign maximum and minimum limits to the usage of individual sires and dams, to force certain usage of specific animals into the solution, and to allow selection of a specified number of dams with each having equal usage.

Calculations

Genetic progress in the selection index defining the breeding objective was predicted at various levels of the constraint on rate of inbreeding for situations where: A) a team of rams with desired genetic contributions was specified, and the goal was to select 1250 ewes from 1763 ewe candidates, and B) ewes selected from situation A above were specified, and rams selected from a list of 29 candidates with minimum and maximum bounds placed on each rams usage, and 2 reference sires forced into the solution.

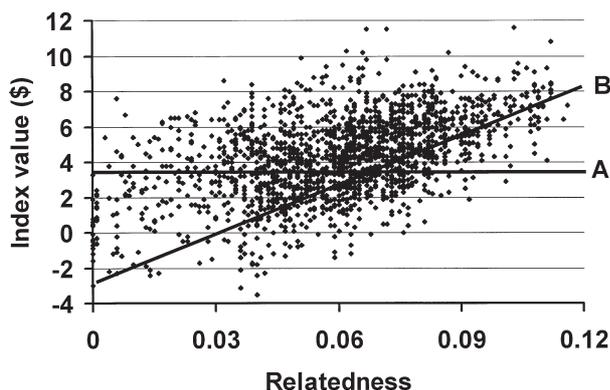
Calculations were based on actual breeding values for rams and ewes in the Awareka flock. For situation A above, only 1.5 year old and older rams were considered with 10 rams having forced contributions of 8% each and one additional ram (with the highest index) forced to have a contribution of 13%. The remaining 7% of contribution from males was assigned among the 11 rams by the optimisation process. Two of the rams were reference rams brought in from outside flocks. One of the reference rams had a number of half sisters within the Awareka flock.

For situation B, an additional 10 ram lamb candidates were available for selection, and any sire chosen to make a genetic contribution was forced to be mated to a minimum of 30 ewes. Restrictions on maximum sire usage were also applied. Ram lambs were assigned an upper limit of 100 ewes and the remaining rams assigned with an upper limit of 150 ewes. The two reference rams were forced to be mated to 100 ewes each.

RESULTS AND DISCUSSION

Figure 1 shows a plot of relatedness against index value for the 1763 ewe candidates considered under situation A. The relatedness value corresponds to the

FIGURE 1. Plot of average relationship with selected ewes of each of 1763 ewe selection candidates against their BLUP selection index value when 1250 ewes are to be selected. All ewes plotted above Line A would be selected if selection was based on estimated breeding value only. All ewes plotted above line B would be selected if the average relationship of selected parents is constrained to be less than 0.077.



weighted average relationship coefficient of each ewe with the sires and selected ewes. The weighting is based on the solution for the expected genetic contributions of each to the next generation with a constraint on overall average relationship coefficients among those individuals selected of 0.077. From Figure 1, it can be seen that the constraint on inbreeding results in the set of ewes below line B and above line A (high relatedness) being replaced by the set of ewes above line B and below line A (low relatedness), relative to the situation where selection is based on breeding values alone. Because the average breeding value of the first set of ewes is only slightly lower than that of the second set, but relatedness is much lower, the tradeoff in genetic progress for a reduction in relatedness is achieved efficiently.

FIGURE 2. Average index value of parents when ewe flock size is reduced from 1763 to 1250 ewes with alternative levels of constraint on the average relatedness of parents. Point A shows the maximum possible average index value of parents, while point B shows an alternative average parental value with lower average relatedness and which corresponds to truncation line B in Figure 1.

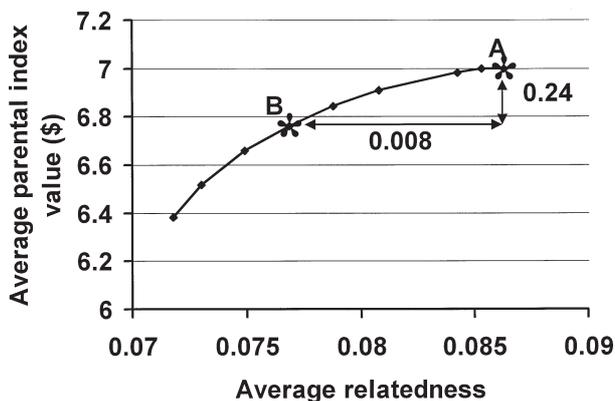
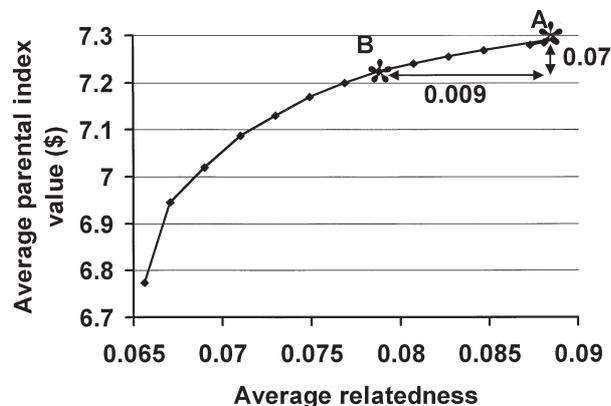


Figure 2 shows the effects on the average index value of parents when applying alternative levels of inbreeding constraint during the optimisation of cull and replacement ewe selection. There is a decrease in the rate of improvement in average index value of parents as the relatedness constraint is relaxed. Selection to reduce flock size based on point B instead of point A results in a \$0.24 reduction in average index value of the parents (approximately 33% of the average annual genetic trend for the flock from 1994 to 2000) and a reduction in average relatedness of 0.008 (approximately 85% of the average annual increase in average relatedness from 1994 to 2000).

Figure 3 shows the effects on the average index value of parents when applying alternative levels of inbreeding constraint during ram team selection. A consistent but modest decline in the rate of increase in average index value of parents is evident as the constraint on average relatedness is reduced. Selection of the ram team based on point B instead of point A results in a \$0.07 reduction in average index value of the parents (approximately 9% of the average annual genetic trend for the flock from 1994 to 2000) and a reduction in average relatedness of 0.009 (equal to the average annual increase in average relatedness from 1994 to 2000).

FIGURE 3. Average index value of parents when a ram team was selected with alternative levels of constraint on the average relatedness of parents. Point A shows the maximum possible average index value of parents, while point B shows an alternative average parental value with lower average relatedness.



The results show how the dynamic selection system can present a range of options to sheep breeders so that they can manage the tradeoff between high rates of genetic progress and accumulation of relatedness. In the absence of substantial immigration of new bloodlines, accumulation of relatedness ultimately leads to inbreeding. Breeders are often reluctant to resort to purchasing outside rams in order to alleviate the risk of inbreeding, because of uncertainty about the genetic merit of the animals they are importing. This is particularly the case for flocks with high rates of genetic progress, and for composite flocks where other flocks with similar breed composition may not be available.

In the absence of dynamic selection tools, breeders often choose to either ignore relatedness and inbreeding, or to incorporate simple modifications to their selection of rams based on their relatedness to other rams they plan to use, as well as to rams they have used previously. It is often not clear whether these simple strategies are effective at controlling relatedness and inbreeding, or whether or not they are costly in terms of lost opportunities to make genetic progress. Dynamic selection procedures make the tradeoff between rate of genetic progress and rate of accumulation of inbreeding transparent, and at the same time, provide very efficient options to trade off one for the other.

The present study has considered a situation in which selection of the ewe flock is followed by selection of the ram team at a later date. It would be useful, in a subsequent study, to quantify any additional benefits from carrying out simultaneous selection of replacement ewes, cull ewes and the ram team. However, in many cases, the sequential approach is necessary because ram team selection is made at the latest practical point prior to the mating season. This is to ensure that all possible sources of information contributing to estimation of breeding values are incorporated into the selection decision. Maintaining surplus ewes and replacements up until this point means that feed is consumed which could otherwise have been used to flush ewes or be carried into the winter.

The choice of how much genetic progress in the index to sacrifice to avoid relatedness was arbitrary for illustrative purposes only. In practice, this decision

involves assessment of a number of complex factors. These factors include the expected effects of inbreeding depression in the breeder's flock, and potentially in his ram buying clients' flocks, the expected reduction in the amount of genetic variation in economically important traits (which affects the rate of genetic progress), and the risk of exposure of a recessive gene giving the breeder a bad reputation. When considering these factors, the breeder must also take account of the fact that there will be a future option to dramatically reduce inbreeding by bringing in outside sires, albeit with the risk of losing genetic progress if the bought-in rams are genetically inferior to home-bred rams.

CONCLUSION

This paper shows that dynamic selection systems can now be applied to sheep breeding programmes to efficiently and transparently manage the tradeoff between the rate of genetic progress, and the rate of accumulation of relatedness among individuals in the population. For many sheep breeders using advanced genetic evaluation tools and ignoring inbreeding, and for those using *ad-hoc* rules when selecting rams in an effort to avoid inbreeding, application of dynamic selection is an attractive option.

ACKNOWLEDGEMENT

We are very grateful to Murray Rohloff for making his sheep breeding pedigree records and breeding value results available for this study.

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