THE EFFECT OF THE SIZE OF MOET NUCLEUS DAIRY CATTLE BREEDING PLANS ON THE GENETIC GAIN AND ITS VARIANCE

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SUMMARY

The effect of the nucleus size and the number of sires selected on the selection response and on it's variance was investigated in adult MOET schemes. The nucleus size was varied from 256 to 4096 animals and the number of sires selected from 4 to 16. The schemes were considered with and without the restriction of selecting only one sire per full sib group.

Restricted schemes were inferior to unrestricted schemes, which selected twice as much sires. Selection of 4 up to 16 sires provided almost the same selection responses in restricted schemes, while the variances of the selection responses were considerably lower when more sires were selected. Increasing the nucleus size caused a marked increase in genetic gain up to a nucleus size of 1000-2000 animals. Above 500 animals, the nucleus size did not affect the variance of the selection response. Here, the number of sires selected determined this variance, which implied that selection of 16 sires was preferred.

INTRODUCTION

Nicholas and Smith (1983) proposed the use of MOET nucleus breeding schemes to exploit the opportunities of the MOET (Multiple Ovulation and Embryo Transfer) technique. These schemes imply selection of sires and dams within a nucleus herd using short generation intervals and based on pedigree and sib information (see Ruane, 1988, and Colleau, 1989, for reviews). The predicted genetic response rates for MOET schemes were up to twice as high as those of conventional progeny testing schemes.

Attempts to exploit MOET nucleus schemes are made in many countries (Kalm and Liboriussen, 1989). The choice of the size of the MOET nucleus herd is of major importance, when a nucleus scheme is established. Juga and Maki-Tanila (1987) reported smaller responses, when simulating the original MOET schemes of Nicholas and Smith (1983). This suggests that the original MOET schemes suffer from reductions of the selection differentials due to small population sizes (see Hill, 1976). Increasing the size of the MOET schemes will overcome this problem.

Criteria for the choice of the population size are 1) selection response; 2) variance of selection response (as a measure for risk of the breeding plan); 3) inbreeding rate; and 4) costs of the plan. Increasing the size of the breeding operation will increase the genetic gain, however with diminishing returns. Similarly, the variance of the selection response and the rate of inbreeding will decrease. The relation between these two criteria is approximately (Hill, 1977):

\[ V(G(t)) = 2 F(t) V_a \] (1)

where \( G(t), F(t) \) and \( V_a \) are the genetic level and the inbreeding coefficient in generation \( t \) and the additive genetic variance.
The aim of this paper is to investigate the effect of the nucleus size on the genetic gain and on its variance. Inbreeding rate and costs of the plans are discussed. The breeding plans considered are adult MOET nucleus breeding plans, i.e. the generation interval is about 4 years. Selection is for milk production; the heritability is 0.25 and the repeatability is 0.4. Milk production is an aggregate trait which might include milk, fat and protein yield.

MODEL

The model will be described in detail elsewhere (Meuwissen, 1990b). A deterministic approach is used to predict the genetic gain and its variance. The selection differentials are approximated using Meuwissen (1990a), accounting for reductions due to family structure. The model also takes full account of variance reductions due to selection, which includes variance reduction due to linkage disequilibrium (Bulmer, 1971) and variance reduction due to previous use of information sources (e.g. selection is among others for dam performance while the dam was selected for individual performance). Variance reduction due to inbreeding is neglected in this model.

The variances of the selection responses were based on the variances and covariances of the selected animals. The model selected those animals, which had the highest probability of selection. The animals with the highest selection probability are those which have the highest expected breeding values, based on order statistics of normal deviates. The variances and covariances of the selected animals are from their relationship (only full- and half sib relations are considered) and from the order statistics of normal deviates.

![Figure 1 The genetic gain. 4-RES (4-UNR) denotes selection of 4 sires with (without) the restriction of selecting one sire per full sib group.](image-url)
BREEDING PLANS

The population sizes considered were 256, 512, 1024, 2048 and 4096 animals per generation. The numbers of selected sires were 4, 8 or 16 and the number of progeny per donor was 8. All breeding plans were considered with and without the restriction of selecting only one sire per full sib family.

RESULTS

The genetic gains of the restricted schemes were always smaller than those of the unrestricted schemes (see Figure 1). Within the unrestricted schemes, the genetic gains of the 4- and 8-sires schemes were almost equal. For small nucleus sizes the 4-sires schemes were slightly superior and for large nucleus sizes the ranking was opposite. The 16-sires schemes had lower genetic gains for all nucleus sizes. Within the restricted schemes, the differences were larger. Here, the 4-sires plans were superior to the 8-sires plans, which were superior to the 16-sires plans.

Figure 2 shows the variances of the genetic gains. In the curves, some irregularities occurred due to the discrete selection of animals from families in this model. In practice there is a probability that an animal is selected from a particular family. The variance of the genetic gain was reduced by restricting the schemes (see Figure 2). A larger reduction of the variance of the selection response was obtained by increasing the number of sires selected. Above a nucleus size of 500 animals, the number of sires selected was the major factor determining the variance of the genetic gain and a further increase of the nucleus size hardly affected this variance. The effect of increasing the nucleus size was smaller for the restricted schemes.

Figure 2 The standard deviation of the genetic gain. 4-RES (4-UNR) denotes selection of 4 sires with (without) the restriction of selecting one sire per full sib group.
DISCUSSION AND CONCLUSIONS

The genetic gains calculated here are of the same order of magnitude as it's variances. Consequently, the genetic level may not increase after one round of selection, which is known from animal breeding practice. However, after many selection rounds the increase of the genetic level is significant (e.g. assume the genetic gain and it's variance are 1 unit per generation, the genetic level, it's variance and it's standard deviation after 25 generations are 25, 25 and 5 respectively).

The restricted breeding schemes had lower response rates than all unrestricted schemes (see Figure 1). Further, the variances of the selection responses of restricted schemes were higher than those of unrestricted schemes, with more sires selected (see Figure 2). Consequently, the restricted schemes are suboptimal: schemes without restricting the selection of full sib sires and with selection of more sires have higher response rates and lower variances of these rates. De Vries et al. reached the same conclusion from simulating pig populations.

Selecting 8 sires is more optimal than selecting 4 sires: the response rates are almost the same and the variances of these rates are much lower for the 8-sires schemes (Figures 1 and 2). Although, the genetic gains of the 16-sires schemes are somewhat less (up to 8%), it seems reasonable to prefer the 16-sires schemes above the 8 sires schemes in view of the reduction in standard deviation of the selection response (up to 25%) and, from Formula (1), it is expected that the inbreeding rate of the 16-sires schemes is \( \pm 45\% \) less than that of the 8-sires schemes.

The optimal nucleus size depends on the extra returns due to increasing the rate of gain by increasing the nucleus size, and on the costs of increasing the nucleus size. At the optimal nucleus size the extra profit equals the extra costs. The increase in rate of gain due to increasing the nucleus size is found in Figure 1. The problem is to find the relation between profit and genetic gain. Dairy cattle breeding organisations are usually in competition. On a competitive market, high costs are justified to obtain a higher genetic level than the competitors (Dekkers, 1989). From Figure 1, it might be concluded that the nucleus size should be at least 1000 animals. Letting it exceed 2000 animals causes only a marginal increase in genetic gain and is probably not advantageous.

REFERENCES