GENETIC AND ECONOMIC VALUE OF MULTIPLE OVULATION AND EMBRYO TRANSFER IN NUCLEUS MERINO FLOCKS

B. GAFFNEY[1], C.M. WADE[1], M.E. GODDARD[1] and F.W. NICHOLAS[2]

[1]Livestock Improvement Unit, Dept. Agriculture, Melbourne 3002
[2]Dept. Animal Science, Univ. Sydney, 2006

INTRODUCTION

Early studies of breeding programs that use multiple ovulation and embryo transfer (MOET) technology indicated that rates of genetic gain much greater than those from conventional breeding schemes could be achieved (e.g. Smith 1986). These gains are largely due to increased intensity of selection on the female side and shortened generation interval. Subsequent work has found that predictions of response need to be revised downwards to allow for several effects that become increasingly important as population size decreases and selection intensity increases. These are the size and family structure of the population; linkage disequilibrium (the Bulmer effect) due to selection reducing the genetic variation available in the future; inbreeding leading to reduced genetic variation and inbreeding depression.

MOET is likely to be most useful in the elite studs that eventually determine the rate of genetic improvement in the whole breed. However it takes some years before improvements in elite studs are reflected in improved production in commercial flocks. This paper estimates the economic return to the industry from investment in MOET within the elite studs. This is done after allowing for the factors listed above which reduce the rate of genetic gain.

METHOD

Breeding programs for stud flocks that incorporate MOET were designed. The elite or nucleus flock produces 2000 surviving lambs each year. The mating ratio using natural service is 3%, and the number of rams used in the MOET schemes is the same as for natural

Table 1. Nucleus flock breeding programs investigated

		MOET					
	Natural service	A2.2	J2.2	A4	J4	A8	J8
Number of rams	68	68	68	68	68	68	68
Number of ewes	2266	909	909	500	500	250	250
Ram ages at breeding	2,3	2	1	2	1	2	1
Ewe ages at breeding	2,3,4,5	2	1	2	1	2	1
Number of lambs surviving per ewe	0.88	2.2	2.2	4	4	8	8

service. The six MOET breeding schemes considered here are designated A2.2, J4, etc, where A and J refer to adult and juvenile schemes respectively, and the digits refer to the number of lambs surviving per ewe. In juvenile schemes, rams and ewes are assumed to be fertile at 6-8 months of age, with lambs born when the parents are one year old. In adult schemes, ewes and rams are first mated at 19 months of age. Breeding animals in the juvenile schemes are selected on performance of sire and dam only, since no information on their own performance is available at mating. Those in adult schemes are selected on their own performance. The trait examined is clean fleece weight. It averages 3.5 ± 0.5 kg, heritability is 0.40 and economic value is $7 per kg. Annual mortality is 5%, and phenotypic inbreeding depression is 0.5% of the population mean per 1% increase in inbreeding. The breeding schemes that were investigated are given in Table 1.

Following standard procedures, the annual rate of genetic improvement is calculated as

$$\Delta G = (i_m r_m + i_f r_f)\sigma_g/2$$

where
ΔG is rate of genetic gain,
i_m, i_f are selection intensities in males and females,
r_m, r_f are accuracies of selection and
σ_g is additive genetic standard deviation.

In addition, annual rate of genetic improvement is calculated using the methodology of Keller et al. (1989), in which selection differentials are adjusted for population size and structure, genetic variance components are adjusted for the Bulmer effect and for the inbreeding which would accumulate over 20 years, and inbreeding depression is accounted for by subtracting $D\Delta F$ from ΔG, where ΔF is the annual rate of inbreeding and D is phenotypic depression per 1% ΔF.

Hill's (1974) gene flow methodology is used to estimate the economic value of a single round of selection in an elite stud or nucleus. The nucleus provides rams or semen to daughter studs containing 43,500 ewes. These daughter studs provide flock rams to commercial flocks containing 1,450,000 ewes and 1,015,000 wethers. The returns are calculated for the schemes listed in Table 1, with either natural mating or artificial insemination (AI) being used at the daughter stud level. The returns are accumulated for 20 years after one year's selection in the nucleus with an inflation-free discount rate of 10%.

RESULTS AND DISCUSSION

The effects of adjusting selection differentials for population size and structure are very small, reducing the response by less than 1%. However, the largest family size used here is only 8 full-sibs; larger family size would lead to a greater loss of selection differential and hence of response. In contrast, reduction in genetic variance due to the Bulmer effect has a quite substantial effect on response, as shown in Table 2. The inbreeding effects shown comprise adjusted selection differentials (used in calculating effective population size), inbreeding depression and the effect of inbreeding on genetic variance.

The effect of linkage disequilibrium (Bulmer effect), which reduces between-family genetic variance, increases with increasing family size. The reduction in response due to this effect is slightly higher for the natural service scheme than for some of the MOET schemes because of a higher intensity of selection in ewes, which have a longer generation

Table 2. Annual rates of response to selection after 20 years for different breeding schemes

Breeding scheme	Standard prediction of annual response (kg)	Reduction in response (%) due to: Bulmer effect	All inbreeding effects	All effects	Annual inbreeding rate (%)	Revised prediction of response (kg)
Natural service	0.090	17	5	21	0.10	0.071
A2.2	0.100	13	5	17	0.13	0.083
J2.2	0.149	14	17	28	0.55	0.107
A4	0.133	17	5	21	0.14	0.106
J4	0.193	17	17	31	0.59	0.134
A8	0.157	18	5	22	0.16	0.123
J8	0.226	18	19	33	0.70	0.151

interval. The accuracy of selection is lower in juvenile than in adult MOET schemes, but the shorter generation interval in juvenile schemes leads to higher cumulative inbreeding over the 20-year period examined here.

At the family sizes assumed here, inbreeding need not be a severe problem. Inbreeding is of major concern in small and intensively selected populations, especially over a long timescale. Furthermore, all its effects have not been fully accounted for here, e.g. inbreeding depression will affect many traits apart from the trait under selection. Its effects could be mitigated by maintaining open nucleus flocks. However, if the animals imported to the flock were of lower genetic merit, then the rate of response would be reduced. An alternative would be for parent studs producing a similar type of sheep to exchange breeding stock, effectively producing a large nucleus flock that comprises the elite flock in each participating stud.

The economic returns to be expected from a single round of selection for schemes in which daughter flocks use either natural service or AI, derived from the revised predictions of response, are presented in Table 3. The results for programs that use natural service at the daughter level show that one round of selection in the nucleus, with natural service used in the nucleus and daughter levels, is worth about $2.75 per commercial ewe, whereas the use of MOET in the nucleus gives returns of up to more than $7 per ewe. The extra returns per lamb born in the nucleus (i.e. returns per base ewe times the number of base ewes divided by the number of nucleus lambs) can be compared with the extra cost of producing lambs by MOET. This shows that the benefits from the MOET schemes are easily sufficient to pay for the costs.

Using AI rather than natural service in daughter flocks produces substantially larger returns per base ewe because the advances made in the nucleus are more quickly passed down to the commercial flocks. The juvenile schemes investigated here were always superior to adult schemes, regardless of whether natural service or AI was used in the daughter tier.

Table 3. Returns from selection after 20 years for different breeding schemes

Daughter flocks		Nucleus flock: Natural service	MOET: A2.2	J2.2	A4	J4	A8	J8
Natural service	$/base ewe	2.75	2.96	4.12	3.67	5.06	4.21	5.72
	$/nucleus lamb	1994	2146	2987	2661	3669	3052	4147
Artificial insemination	$/base ewe	2.91	4.94	5.69	5.75	6.69	6.25	7.41
	$/nucleus lamb	2110	3582	4125	4169	4850	4531	5372

The results indicate that substantially greater response to selection may be achievable through the use of MOET in stud ewes, especially in combination with AI at lower levels of the breeding pyramid. Inbreeding may largely be mitigated by the exchange of breeding stock between studs. There might be considerable loss of potential genetic progress, however, if a small, closed stud flock were subjected to an intensive and repeated MOET program. With an adult nucleus flock of just 7 rams and 25 ewes, for example, the revised prediction of response to selection is 54% less than the standard prediction, with inbreeding accounting for about 35% of the decrease. With a juvenile nucleus of the same size, inbreeding depression rapidly outweighs potential gains.

The costs of MOET are still considerable. For our top, most influential flocks however, there are large potential benefits from MOET schemes. As costs should decrease and reliability improve, the benefits should correspondingly increase. Proper use of MOET in stud flocks has the potential to increase rates of genetic improvement in those flocks and, after an initial lag, in flocks of the stud's clients.

Although the results presented here are for selection on fleece weight, similar results apply for selection on other traits or combinations of traits if their economic value is similar to that of fleece weight. The benefits in Table 3 are for the industry as a whole. The individual stud investing in MOET makes its profit by selling the superior rams at a higher price. For this to happen the ram buyer must be able to perceive the superior genetic merit of the rams, perhaps through a sire evaluation scheme.

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