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GENETIC PROGRESS FROM PERFORMANCE AND PROGENY TEST SELECTION IN DOWN SHEEP

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SUMMARY

An examination is made of some factors which will affect the efficiency of selection for increased lamb weights. Parameters chosen and flock sizes studied are as assumed for recorded flocks of meat breed sheep in New Zealand. The factors studied include: flock size, fertility level, heritability level, combined individual performance plus progeny test versus individual selection alone, number of young rams and of progeny-tested rams selected each year, age of rams when used, proportion of ewes mated to young rams versus older rams, and mating capacity of rams. Within flock size and fertility level, the expected genetic gain in lamb weight varies markedly, depending on the combinations of these factors.

INTRODUCTION

The New Zealand sheep recording service (Sheeplan) provides the breeders with processed information which can be used in selection decisions. This information depends on the characters the breeders choose to record and on whether the breed type is dual-purpose or specialized meat.

Two important outputs from Sheeplan are the two-tooth selection list for rams and ewes, and the sire summaries. Breeding values in the two-tooth selection list for the meat breeds are presented for number of lambs born (or reared) based on the dam's performance, and weaning weight and autumn liveweight based on own performance. The sire summary shows the sires' predicted breeding values for weaning weight and autumn liveweight, based on performance of progeny.

Selection for increased lamb weight using the two-tooth selection list may, for the meat breeds, be regarded as selection on individual performance. Selection of rams on the basis of sire summaries is progeny test selection.

This study examines some factors which will affect the efficiency of selection for increased lamb weights in meat breeds, when this selection is based on the two-tooth selection list and sire summaries.

METHODS

The average size of recorded flocks of meat breed sheep in New Zealand is about 120 ewes, and the effect of selection is studied in five different flock sizes, varying from 50 to 500 ewes. Three fertility levels are considered, namely, 0.8, 1.0 and 1.2 lambs weaned per ewe.

Main consideration is given to selection for weaning weight which is assumed to have a heritability of 0.10 and a genetic standard deviation of 1 kg (Clarke and Rae, 1976). Some consideration is, however, also given to traits with heritabilities of 0.05 and 0.20.

Annual genetic gain resulting from one-stage and two-stage selection (performance and performance plus progeny test selection, respectively) of rams is calculated by means of the method given by Dickerson and Hazel (1944). By this method the rams are, at the second selection stage, evaluated on the basis of an index combining both own and progeny performance. However, such a procedure is not yet available in Sheeplan and selection on progeny performance only at the second stage is therefore assumed here.

The method of Cochran (1951) (assuming large populations) is used to allow for reduced genetic variance among sires as a result of selection on individual performance. It is assumed that selection is carried out within flocks, and in transforming proportions selected to selection differentials allowance has been made for limited sample size (Becker, 1967).

The effect of a number of factors on the expected annual genetic gain is studied. These factors are: number of young performance-selected rams entering the flocks each year, age of young rams when first used (*i.e.*, as ram lambs or as 1½-year-olds), proportion of ewes mated to young rams versus older proven rams, number of proven rams selected, and mating capacity of young and older rams.

The effect of flock size, fertility and heritability level is also investigated.

When progeny test selection as a supplement to performance selection is studied, it is assumed that the proven rams are used for one year only, immediately following the progeny test. Thus the proofs must be available before the next mating period.

The generation interval dam-progeny is assumed to be four years, and 27% of the ewes each year being replaced by performance selected young females.

RESULTS

NUMBER OF YOUNG RAMS SELECTED EACH YEAR

The number of young rams selected each year clearly affects the selection differential in the first selection stage, and accordingly the expected genetic progress from this part of the selection process. However, selection of very few rams at this stage will limit the intensity of subsequent progeny test selection.

Figure 1 shows the effect for three flock sizes (50, 100, and 250 ewes) of varying the number of young rams selected both when only the first selection stage — *i.e.*, performance selection — is applied and when a combination of performance and progeny test selection is carried out. It is here assumed that ram lambs are used as young rams, and that these, when progeny testing is intended, are mated to an optimum proportion of ewes.

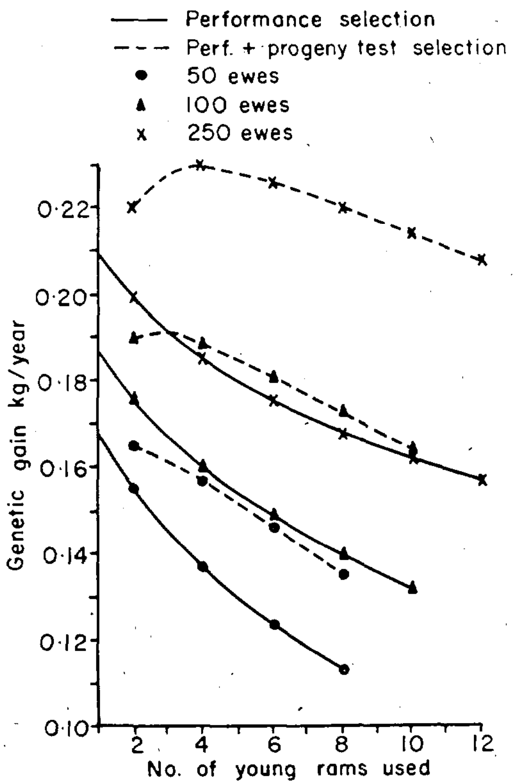

FIG. 1: *Effect of varying the number of young rams used.*

The ewes are assumed to have one lamb each, and only one progeny-tested ram is selected each year.

Increasing the number of young rams selected each year, or reducing the ewe:ram ratio, has a major effect on genetic gain under performance selection. Where a combination of performance and progeny test selection is applied, the expected genetic gain increases as the number of young rams increases up to 3 and 4, respectively, for flock sizes of 100 and 250 ewes. For a flock of 500 ewes, the corresponding optimum number of young rams used is 5.

Figure 1 illustrates the well-known fact that one may expect in larger flocks both greater genetic gain and greater relative advantage of breeding programmes, including progeny testing. However, if rams are selected solely on performance (and inbreeding effects be ignored), similar genetic progress can be achieved in 50-ewe flocks with one sire as in 100-ewe flocks with three sires, and in 100-ewe one-sire flocks as in 250-ewe four-sire units.

The number of young rams selected each year can vary more, without serious consequences, when progeny testing is included

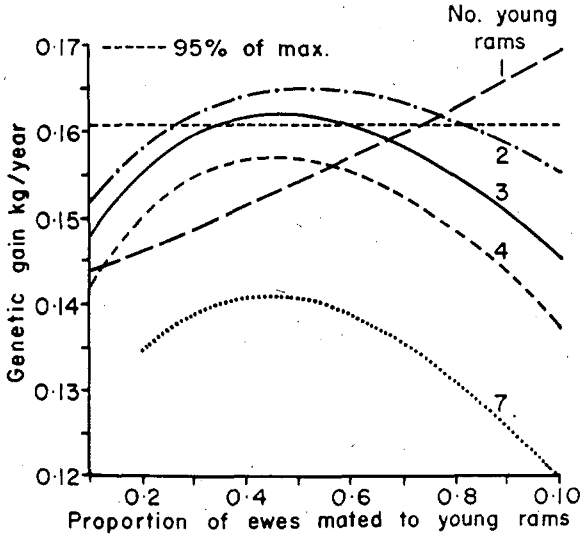

FIG. 2: *Effect of varying the proportion of ewes mated to young rams. Flock size = 50 ewes.*

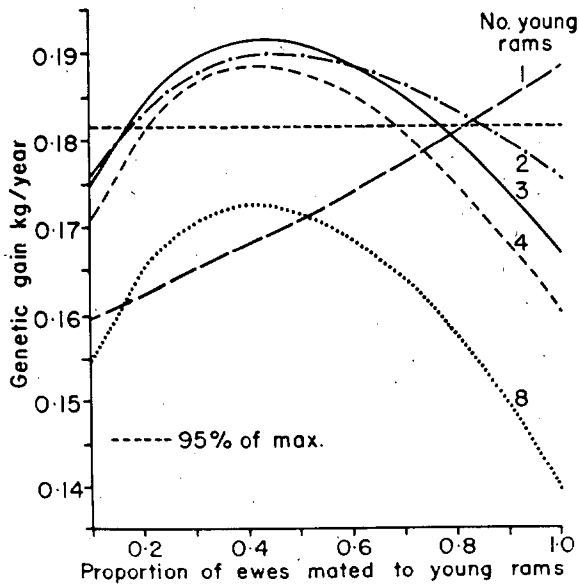

FIG. 3: *Effect of varying the proportion of ewes mated to young rams. Flock size = 100 ewes.*

into the flock's breeding programme than when performance selection only is applied.

PROPORTION OF EWES MATED TO YOUNG VERSUS PROVEN RAMS

In Figs. 2, 3, and 4 the effect of mating a varying proportion of the ewes to young rams (ram lambs) is indicated. The flock sizes represented are 50, 100 and 500 ewes with one lamb weaned per ewe, and it is assumed that ewes not mated to young rams are mated to the best progeny-tested ram from the previous year. The heritability assumed is 0.10.

Greatest genetic gain is achieved in flocks of 100 to 250 ewes when 40% of the ewes are mated to young rams. The corresponding optimum proportions are 50% for 50-ewe and 30% for 500-ewe flocks, respectively. It can be seen. however, that the optimum proportion is not very sharp. In fact, mating the best two rams in a 50-ewe flock to anything between 25 and 80% of the ewes will give at least 95% of the maximum genetic progress

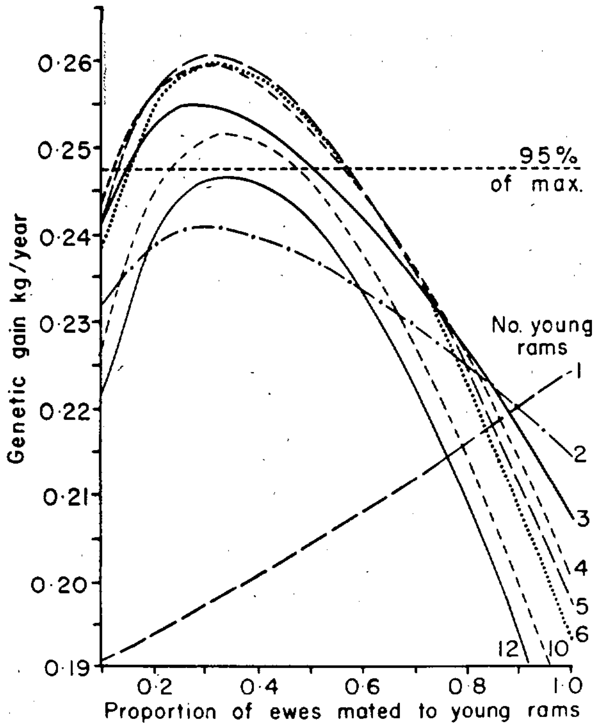

FIG. 4: *Effect of varying the proportion of ewes mated to young rams. Flock size = 500 ewes.*

which can be expected in this population, namely, mating all ewes to the very best young ram.

If three young rams are selected and selection of the best of these after progeny test is intended, these three rams should be mated to between 35 and 55% of the ewes, if 95% of maximum progress is to be achieved. Moving to a 500-ewe flock (Fig. 4), the advantage of using progeny test in addition to performance selection is greater, and the proportion of ewes mated to young rams becomes somewhat more critical. However, if an optimum number of young rams is tested (4 to 6), between 15 and 55% of the ewes can be mated to young rams without losing more than 5% of the maximum genetic gain, which in this case is obtained by testing 5 rams on 30% of the ewes. If as many as 10 young rams are used, in a 500-ewe flock, they have to be mated to between about 23 and 47% of the ewes if 95% of maximum progress is to be obtained.

Especially if the young rams are mated to a considerably larger proportion of ewes than optimum, the effect of increasing the number of rams will have a larger negative effect than Fig. 1 indicates. For flock sizes between 100 and 500 ewes, this seems to be the case when the proportion of ewes mated to young rams is larger than about 70 to 80%. Of course, as this proportion approaches 100% the whole selection process goes on to be performance selection only, and the negative effect of increased ram number correspondingly large.

Number of Progeny-tested Rams Selected

So far it has been assumed that only one progeny-tested ram has been selected each year. With an optimum proportion of ewes mated to young rams, this means that the selected proven ram must mate 25, 60, 90, 150 and 350 ewes, when the flock sizes are 50, 100, 150, 250, and 500 ewes, respectively. Especially for the largest flock size, this may exceed the mating capacity of 1½-year-old rams. The question then arises of what effect selection of 2 or even 3 rams may have on the genetic progress. Figure 5 illustrates the situation for a 500-ewe flock.

While 5 young rams tested each year is the optimum number when 1 proven ram is selected, 7 young rams tested will have a very slight advantage (1%) if 2 proven rams are selected. If 3 proven rams are needed, 9 young rams should be tested each year on a slightly larger proportion of ewes than where 1 of 5 is needed. The advantage of testing 9 instead of 5 when 3 proven rams are needed is, however, not more than 4%.

If 2 proven rams are needed, and they are used to the same extent, the expected annual genetic gain will be only 91% of that where only 1 proven ram is needed in a 500-ewe flock. And if 3 proven rams must be used, the corresponding figure is 86%. Thus, the number of proven rams selected has a pronounced effect on the genetic gain that can be expected.

Fertility Level

The number of lambs per ewe available for recording and selection has a marked effect on expected genetic gain. When the number of lambs increases from 0.8 to 1.0, and only performance selection is applied, the expected genetic progress will increase by 11 to 13%, with largest effects in the smallest flocks. When the number of lambs increases from 0.8 to 1.2, one should expect an increase in progress of 20 to 22%, assuming ram lambs are mated to 50 ewes each.

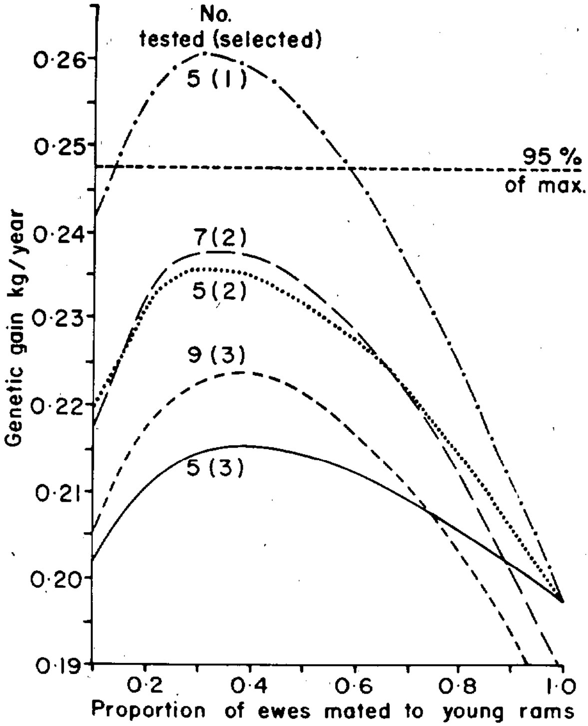

FIG. 5: *Effect of the number of progeny tested rams selected each year. Flock size = 500 ewes.*

Where an optimum combination of performance and progeny test selection is carried out, the average relative increase in genetic progress with increasing fertility level is about the same as for performance selection only. However, in this case the smallest flocks will benefit much more than the largest flocks. When number of lambs increases from 0.8 to 1.0 and 1.2, 50-ewe flocks should expect increases of 14 and 24%, respectively. The corresponding figures for 500-ewe flocks would be 9 and 16%. The effect of increased fertility on genetic gain is so large that it may enable small flocks with high fertility to have the same, or higher, genetic gain than larger flocks with lower fertility.

RAM LAMBS VERSUS TWO-TOOTH RAMS AS "YOUNG" RAMS

In Figs. 2, 3 and 4, the line for one young ram indicates a situation where only phenotypic selection is possible (since no selection on progeny performance can be applied). In proportion as the young ram is mated to an increasing number of ewes, older rams are mated to a decreasing number. Accordingly, the generation interval is reduced and the expected annual genetic gain is increased.

Under solely phenotypic selection with rams used for only one year, the genetic gain per year could be raised by 20% by using ram lambs instead of two-tooth rams. If the rams are used on an equal proportion of ewes over two years, the advantage would be 18%. It may be argued that the mating capacity of two-tooth rams is considerably larger than the capacity of a ram lamb and that this could lead to more intense selection if two-tooth rams were used.

This situation is illustrated in Table 1 for a flock of 500 ewes, each weaning one lamb, and using only phenotypic selection.

TABLE 1: EFFECT OF USING TWO-TOOTH RAMS WITH LARGER MATING CAPACITY THAN RAM LAMBS
(500-ewe flock, one lamb per ewe)

Mating Age (yr)	*No. Rams*	*Ewes/Ram*	*Gain/yr (kg)*	*Rel. Gain*
½	10	50	0.181	100
1½	10	50	0.151	83
1½	5	100	0.164	91
1½	2	250	0.178	99

When the mating capacity of a two-tooth ram is five times that of a ram lamb in this example, the genetic gain from using two-tooth rams is almost the same as that expected from using ram lambs. An extra advantage of using ram lambs in this case might be the effect of an increased number of rams in lowering the rate of inbreeding in the flocks.

For the alternatives of combined performance and progeny test selection studied, the advantage of using ram lambs instead of two-tooth rams varies betwen 17 and 20% when the proportion of ewes mated to young rams varies between 10 and 90%.

Heritability Level

The extra benefit from progeny testing as a supplement to earlier performance selection is greater when the heritability is low than when it is high. To investigate this more closely for the present case, calculations were carried out for flock sizes of 100 and 500 ewes, assuming heritabilities of 0.05 and 0.20. The optimum structure with respect to number of rams tested and proportion of ewes mated to young rams did not appear to be changed compared with a case where the heritability is 0.10.

The relative advantage of optimum performance plus progeny test selection over performance selection alone with heritabilities of 0.05, 0.10 and 0.20 and one lamb weaned per ewe is shown in Table 2. Two different mating capacities of ram lambs and two-tooth rams are assumed.

TABLE 2: EFFECT OF HERITABILITY ON THE RELATIVE ADVANTAGE OF PERFORMANCE PLUS PROGENY TEST SELECTION
(Performance selection alone = 100)

Flock Size	*Heritability*	*Ewes per Ram Lamb/Two-tooth Ram* 25/100	100/200
100	0.05	123	104
	0.10	120	102
	0.20	115	98
500	0.05	142	131
	0.10	137	124
	0.20	130	116

The relative effect of variation in the heritability is largest under conditions where progeny testing is of most importance, namely in large flocks, and where the mating capacity of ram lambs is low relative to the capacity of older rams.

DISCUSSION

The present calculations indicate that progeny testing in addition to performance selection may be of some advantage in recorded flocks of meat breed sheep in New Zealand. However, apart from flock size and heritability, the relative advantage of progeny testing may also be dependent on the mating capacity of ram lambs versus older rams, as indicated in Table 2.

In Table 3 the relative effect of performance plus progeny test selection versus performance selection alone is shown for a num-

TABLE 3: RELATIVE EFFECT ON ANNUAL GENETIC GAIN OF PERFORMANCE PLUS PROGENY TEST SELECTION COMPARED WITH PERFORMANCE SELECTION ALONE, WHEN MATING CAPACITY OF RAM LAMBS AND TWO-TOOTH RAMS VARIES

	Ewes per Ram Lamb/Two-tooth Ram				
Flock Size	*25/100*	*50/150*	*50/200*	*85/200*	*85/350*
50	106	97	97	97	97
100	120	109	109	109	109
150	130	118	118	112	112
250	134	127	127	120	120
500	137	131	135	127	135

Heritability = 0.10
No. of lambs/ewe = 1.0
"Young" rams = ram lambs

ber of combinations of mating capacities of ram lambs and older rams, and for all flock sizes studied.

Clearly, as long as the capacity of ram lambs is less than the number of ewes in the flock, an increased capacity may increase the possibility of selection on own performance, and increase genetic gain under straight performance selection. The mating capacity of ram lambs is not critical when progeny test selection is applied. As shown earlier, the optimum proportion of ewes which should be mated to young rams is not very critical around the optimum, and the optimum number of ewes which should be mated to each ram is never larger than 30. Therefore, it may sometimes pay to increase the number of ewes mated to young rams somewhat to reduce the number of proven rams selected. For instance, the best result in a 500-ewe flock is obtained when the very best out of 5 young rams mated to 30% of the ewes each year is selected. This means, however, that the proven ram has to mate 350 ewes and 2 proven rams may be needed. However, selecting the best ram out of 6 young ones tested on 60% of the ewes (300 ewes) would give a slightly better result, and the best which can be achieved in a flock of 500 ewes when the mating capacity of the proven ram is 200, and of the young rams at least 50 ewes.

Using rams for the first time, both in performance and combined performance and progeny test selection, when they are 1½ years would reduce the advantage of progeny testing. For instance, in a 100-ewe flock the advantage of progeny testing would then be about 4% if only one 1½-year-old ram was needed. In fact, progeny test selection suffers more from increased age of rams than does performance selection, since the disadvantages of increased generation interval under performance test can be partly cancelled by larger mating capacity and stronger selection. The optimum number of ewes which should be mated to each young ram in a programme including progeny testing is never so large that the full mating capacity of rams older than ram lambs can be exploited.

The results of the present study indicate what on average could happen in a large number of closed flocks. However, it is possible that the total response of selection will vary quite markedly among flocks after selection has been going on for some time, and as a result of genetic drift.

Exchange of young and proven rams among flocks seems to be a wise policy. This would level out the effects of genetic drift and reduce the rate of inbreeding. As far as inbreeding is concerned, it is difficult to see any important difference between a breeding programme based on performance selection only and one including progeny testing, when the maximum possibilities for intense selection are exploited in both cases and performance selection only is used to select the young rams.

The purpose of selecting for increased lamb weight in meat breeds is to increase the weight of their crossbred progeny in commercial flocks. Thus, the success of this selection, both on the basis of own performance and on purebred progeny, depends on the genetic correlation between purebred and crossbred performance. If this correlation is low, the value of selection within recorded purebred flocks of meat breeds is also low. Rae (1976) suggests a breeding programme for meat breeds where the rams are progeny tested on the basis of their crossbred progeny in other flocks. This would offer an extra advantage if the mentioned correlation is low. However, the intention of the present study was to investigate the possibilities of performance and progeny test selection in recorded flocks of meat breeds, where such auxiliary test flocks are not available.

Even if selection on the basis of progeny testing in the present study is found to be of some advantage, the larger part of the genetic gain will come from performance selection of young rams and ewes (selection on the basis of the ewes' productivity is not considered in this study). Assuming a fertility level of one lamb per ewe, about 78% of the genetic gain in a 100-ewe flock is expected to come from performance selection of both ram and ewe replacements, and 57% to come from performance selection of young rams alone. In a 500-ewe flock, 66% of the progress is expected to come from performance selection, and 51% from performance selection of rams. Selection of young rams on the basis of their own performance is therefore the single factor contributing most to the genetic gain under the assumptions made here.

ACKNOWLEDGEMENT

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