
THE PROCEEDINGS OF THE
NEW ZEALAND SOCIETY
OF
ANIMAL PRODUCTION
VOLUME 62 2002

# Cost benefit analysis of commercial use of the Inverdale prolificacy gene

P.R. AMER, J.C. McEWAN, K.G. DODDS AND G.H. DAVIS

AgResearch, Invermay Agricultural Centre, Private Bag 50034, Mosgiel, New Zealand.

## ABSTRACT

The Inverdale prolificacy gene is one of several potential major genes currently being explored for commercial application to the New Zealand sheep industry. We calculated economic benefits of two strategies to breed Inverdale carrier stud rams using gene flow methodology. Strategy 1 involves continuous transition matings from a conventional stud flock to generate Inverdale carrier ewes while Inverdale carrier ewes are self replacing in Strategy 2. Strategy 1 involved less DNA testing per ram sold, resulting in a $140 saving in testing costs at $50 per test. Reduction in conventional genetic response was also lower for Strategy 1 (<5% as opposed to 24% for Strategy 2) although Strategy 1 requires closer monitoring of animal identification and some Inverdale rams must be kept to produce carrier ewes. Commercial Inverdale use was shown to be highly beneficial in an existing terminal sire mating system with an added value over a normal ram of $3350 per Inverdale ram purchased. This was also highly cost effective with an expected DNA test price of $50 to $75 per sheep genotyped.

**Keywords:** sheep; Inverdale; breeding structure; major gene; economic benefit.

## INTRODUCTION

The Inverdale gene (FecX) located on the X chromosome of sheep affects ovulation rate and therefore indirectly number of lambs weaned (Davis *et al*., 1991). A preliminary evaluation of the economic benefits (McEwan *et al*., 1995) suggested that it would be profitable to use the Inverdale gene in New Zealand under certain conditions. A DNA based marker test has recently been developed so that the three-tiered breeding structure with a ram breeder producing rams known to carry the Inverdale gene in the top tier, as proposed by McEwan *et al*., (1995), can now be implemented. Official launch of the Inverdale prolificacy gene to industry took place late in 1997 with a field day on the property of Arnold Gray, near Tuatapere in Southland.

The present economic evaluation extends previous work in several areas. Updated estimates of the economic value of increasing prolificacy through use of the Inverdale gene (Amer *et al*., 1998) are incorporated along with a description and economic evaluation of two alternative strategies for stud breeders to produce Inverdale carrier rams. The cost of delays from the initial purchase of Inverdale rams by stud breeders until slaughter of the additional lambs produced by Inverdale ewes is also accounted for using discounted gene flow theory.

## MATERIALS AND METHODS

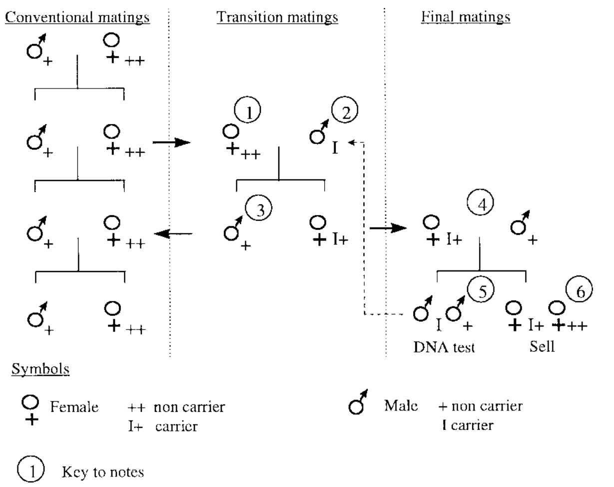
Two Inverdale ram breeding schemes are described and their costs calculated in this section. Discounted gene flow coefficients (Amer , 1998) are then used in conjunction with the economic value of increased lambs born per ewe lambing (Amer *et al*., 1988) to estimate a break even price premium for Inverdale carrier rams for alternative existing commercial mating systems.

### Continuous transition scheme for Inverdale rams (Strategy 1)

The first mating strategy to produce known Inverdale carrier rams is outlined in Figure I. The key point with this strategy is that the gene is maintained in the flock through recycling males carrying the Inverdale gene. Non carrier females are therefore required, the source of these being a conventional stud flock run in conjunction with transition and final Inverdale matings. More specific notes corresponding directly with numerals marked on Figure I are as follows:

1. Females with high breeding values for a multiple trait selection index excluding number of lambs born are chosen from the conventional stud flock and mated with an Inverdale sire.
2. Inverdale sires must initially be bought in but can become self replacing two generations (4 to 5 years) later.
3. Male progeny of Inverdale sires are non carriers so they can be considered as potential future sires in the conventional stud flock or marketed as commercial non carrier rams.
4. In the final matings, unrelated males from the conventional flock (high breeding values for index excluding NLB) are mated to carrier ewes. Carrier ewes could be subsequently managed separately from the conventional flock to minimise any setbacks to their offspring due to the expected larger litter sizes.
5. Male offspring of Inverdale carrier ewes require a DNA test. To minimise testing costs, the DNA test should follow final culling on acceptability for sale. Rams can be marketed according to genotype (ie. carriers as Inverdale sires and non-carriers as conventional sires). Note that in the long term, non-carrier rams will be of similar average genetic merit to the conventional sires.

**FIGURE I:** Ram Breeding Strategy 1 - Continuous transition. Numerals marked in the figure correspond to notes in the text.




6. Female offspring of Inverdale carrier ewes are of unknown Inverdale genotype and should be sold.

**Self sustaining scheme for Inverdale rams (Strategy 2)**

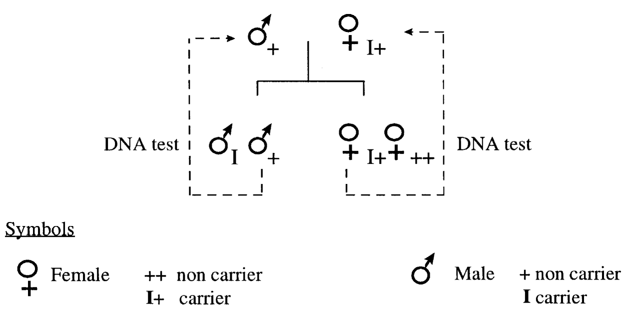
The self sustaining strategy described here provides an alternative to the transition scheme whereby the gene is maintained in an Inverdale flock (potentially closed to outside animals). This is done through identifying female lambs carrying the Inverdale gene and identifying normal, non carrier, male lambs and using these to breed future replacements. Figure II shows the mating and DNA testing requirements associated with this strategy.

**Commercial flock structure with Inverdales**

Inverdale carrier ewes should not be mated to Inverdale carrier rams because on average, half of the ewe progeny will be infertile. Therefore, three groups of matings are required for commercial use of the Inverdale gene as follows; 1. Normal ewes to normal rams (to maintain a pool of normal ewes) , 2. Normal ewes to Inverdale carrier rams (to produce Inverdale ewes) and 3. Inverdale ewes to a terminal sire. These matings may be carried out on one or more farms.

Because of constraints on the total flock size and the need to maintain a normal flock of ewes, there is an upper limit to the number of Inverdale ewes which can be generated and this is dependant on several aspects of flock performance. We define **N** as the number of normal ewes mated to normal sires, **M** as the number of normal ewes mated to Inverdale sires, and **I** as the number of Inverdale ewes mated to a terminal sire. The total number of ewes **(E)** might be calculated as **E=N+M+I.** However, we will know the total number of ewes for a farm in advance, and it is how the total number is divided up into ewes for each tier which will be of interest.

**FIGURE II:** Ram Breeding Strategy 2 - Self sustaining.




It is convenient to initially calculate a maximum potential replacement rate, r, as $r = j \times \frac{v}{2} \times k$ where j is the average number of joinings per ewe lifetime (for example 3 to 5 might be typical values), v is the average number of lambs reaching replacement age per ewe joined (can be approximated as the lambing percentage expressed as a proportion) and k is the proportion of ewe hogget replacements which survive farm culling (for example 0.7 to 1.0 might be typical). Normal values for r are expected to range from 1.1 to 2.5.

The number of normal ewes mated to Inverdale sires is calculated as follows:

$$\mathbf{M} = \frac{\mathbf{E}}{1 + \frac{v}{r-1} + r}$$

The number of Inverdale ewes is calculated as **I** = **M** x r, while the number of normal ewes mated to normal sires is calculated as

$$\mathbf{N} = \frac{\mathbf{M}}{r-1}$$

**Commercial benefits of Inverdale**

Calculations of the commercial benefits of the Inverdale gene were based on results from two related studies. It was assumed that the breeding structure prior to the introduction of the gene already involves using a terminal sire on surplus females, not required to produce flock replacements. In this situation, we can assume that the benefits from using a terminal sire already out-weigh the costs of reduced culling, otherwise the terminal sire system would have been abandoned. Thus, the cost of reduced culling and the benefits of using a terminal sire are not attributable to ewes carrying the Inverdale gene. Amer (1998) calculated the discounted number of expressions for ewe lambing traits for a sire breeding terminal female daughters (all offspring slaughtered) to be 335, when it was assumed that the Inverdale carrier sire was used for 3 years and that 90 ewes lambed per sire. The economic value per Inverdale carrier ewe lambing was calculated by Amer *et al*., (1998) for alternative farm types. Because the Inverdale carrier ewes are most likely to be run in easy to moderate environments where lamb survival in triplets is in the region of 70% or higher, a value per ewe lambing of $10 was assumed (Amer *et al.*, 1998).

## RESULTS

**Inverdale rams**

Table 1 summarises the advantages and disadvantages of the two Inverdale ram breeding strategies considered. There are four groups of costs to the stud breeder producing Inverdale rams using the continuous transition strategy (Strategy 1). These include ram genotyping, opportunity cost of Inverdale rams, lost genetic response for

**TABLE 1:** Summary of costs and other issues per ram sold associated with continuous transition and self sustaining stud breeding strategies to produce Inverdale (I) carrier rams.

| | Continuous transition (Strategy 1) | Self sustaining (Strategy 2) |
|---|---|---|
| *Costs* | | |
| Male DNA test | $100 (2 DNA tests) | $100 (2 DNA tests) |
| Retained I males | $25[1] | - |
| Female DNA test | - | $150 (3 DNA tests) |
| Additional Management | $67 | - |
| **Total costs** | $192 | $250 |
| *Other issues* | | |
| Lost genetic response | <5% per year | 24% per year |
| Scope for breed integration | yes | yes |

[1] This cost is equal to 5% of the $500 premium paid for an Inverdale carrier sire.

quantitative traits and increased flock management costs. Provided that all potentially marketable rams are kept until a decision is made on their acceptability for sale, there will be two DNA tests of male offspring required for every ram identified as carrying the Inverdale gene. We assume that the cost of genotyping is $50. Initially, at least one Inverdale carrier ram must be purchased from outside the flock. Subsequently, Inverdale rams identified by gentoyping male offspring from the final matings could be used for transition matings although this would involve lost revenues in terms of the opportunity cost of the sire's sale value. Fortunately, only a relatively small number of transition sires are required per Inverdale carrier ram marketed and so it is expected that the opportunity costs of transition Inverdale rams will be less than 5% of the difference in sale value of the best young Inverdale ram and an elite stud ram (probably less than $30 per stud ram sold).

All ewe lambs and half of the ram lambs (Inverdale carriers) from Inverdale carrier ewes will be unavailable for selection within the conventional stud flock. The selection intensity in female progeny resulting from transition matings (to produce Inverdale carrier ewes) will also be minimised which potentially results in an additional loss in selection intensity in the conventional flock. However, we have carried out calculations which show that the loss of genetic gain in the conventional stud with this Inverdale scheme will generally be modest (5% or less).

Accurate pedigrees are already required in stud flocks but there will be extra recording costs and stud flock management associated with the transition structure. We assume an additional management cost of $20 per Inverdale carrier ewe (excluding extra feed requirements) which translates to $67 per Inverdale carrier ram sold. Extra feed requirements for Inverdale carrier ewes in the stud are expected to be offset by the higher number of rams born per Inverdale ewe.

The three main groups of costs to the stud breeder producing Inverdale rams according to the self sustaining flock design (Strategy 2) are ram genotyping, ewe genotyping and lost genetic response. Ram genotyping costs are the same as for the continuous transition flock described above. Because half of the ewe lambs are non carriers, on average two genotype tests will be required per identified carrier. It is assumed that 30% of Inverdale carrier ewe lambs are culled post weaning, but before DNA testing, and that 40% of Inverdale carrier rams are culled. If Inverdale ewes wean 1.7 lambs in the stud, and average 4 lambings per stud ewe lifetime, there will be approximately 3 ewe genotype tests per Inverdale carrier ram sold.

The selection intensities in both male and female progeny are lower than for a conventional flock because only half of each sex will have the desired genotype (we assume that young non carrier rams are used as opposed to bought in rams). However, the effect is somewhat moderated for ewes because the more prolific Inverdale ewes produce more ewe lambs which are available for selection. Our calculations show that the overall expected reduction in flock genetic response is approximately 24%. Thus, neither of the two strategies is clearly best, each has advantages and disadvantages.

**TABLE 2:** Matings of normal and Inverdale ewes in a commercial flock using the Inverdale gene (all male offspring slaughtered)

| Mating | Percent of ewes[1] | | | Female offspring |
|---|---|---|---|---|
| | **Low** | **Med** | **High** | |
| **Tier 1** | | | | |
| Normal ewes to normal rams | 61% | 39% | 18% | Mated to Inverdale and normal rams |
| **Tier 2** | | | | |
| Normal ewes to Inverdale rams | 17% | 23% | 25% | Mated to terminal sire |
| **Tier 3** | | | | |
| Inverdale ewes to terminal sire | 22% | 38% | 57% | Slaughtered |

[1] Low corresponds to a flock with a lambing percent of 100 and 20% of ewe replacements culled. Med. corresponds to a flock with a lambing percent of 115 and 10% of ewe replacements culled. High corresponds to a flock with a lambing percent of 125 and 5% of ewe replacements culled.

## Commercial flocks

Table 2 outlines the matings which should take place as part of an ongoing tiered structure for commercial flocks using the Inverdale gene. Larger proportions of Inverdale carrier ewes can be maintained if the flock lambing percentage is above average, with light culling of ewe replacements (compare low versus high situations in Table 2) and when ewe longevity is good. This is because in these situations, a lower proportion of ewe lambs are required to maintain the normal ewes in tiers one and two.

The break-even price premium which could be paid for each Inverdale carrier ram over the purchase price of a non-carrier ram calculated as the number of expressions of the terminal ewes multiplied by the value of $10 equals $3350 per Inverdale ram purchased.

## DISCUSSION

When producing Inverdale carrier rams, the continuous transition strategy requires less genotyping than the self replacing strategy because females produced from the transition matings are automatically known to be carriers, and the need for testing of females is negated (Table 1). There is also greater flexibility with the continuous transition strategy because the Inverdale matings can be carried out as a small extension of a relatively unaffected, but moderate to large sized (200 stud ewes or more) conventional stud flock. Maintenance of a self sustaining Inverdale flock would require a larger critical mass of ewe numbers to avoid inbreeding unless normal rams from an outside (non Inverdale) flock are introduced on a regular basis. The self sustaining system with regular introduction of non carrier rams might therefore be most suitable for relatively small flocks prepared to market 50% of rams as known Inverdale carriers.

The continuous transition system allows benefits of selection in the conventional stud flock to be captured in both Inverdale and normal rams produced as a result of transition or final matings. However, it would probably be optimal to reduce selection emphasis for prolificacy in the stud flock and increase emphasis on traits expected to improve the maternal ability of dams. A moderate to large sized self-sustaining flock would have more scope to focus selection on traits which complement the prolificacy boost provided by the Inverdale gene.

There is scope for breed integration in both strategies, although the continuous transition strategy is more flexible. For example, the ram used in the final matings of the continuous transition strategy (see right hand side of Figure I) could be from a specialised meat breed. Rams marketed would subsequently have one half of these genes, while their sons (slaughtered) and daughters (breeding ewes) would have one quarter of these genes. Introduction of a new breed into the self sustaining strategy would have longer term implications because there is a greater degree of recycling through replacements obtained from within the Inverdale flock.

The break-even price premium which could be paid for each Inverdale carrier ram of $1760 for a flock structure currently using a terminal sire substantially out-weighs the costs (less than $500) for the stud to produce the Inverdale ram. Additional calculations (results not shown) indicate that the Inverdale gene is also highly profitable for other commercial flock situations. For example, the reduction in ewe hogget replacement culling which results when a straight breeding flock switches to a tiered Inverdale system are largely offset by the additional benefits of using a terminal sire over a proportion of the flock.

From a financial perspective, the value of the Inverdale gene in commercial sheep production should easily justify sufficient price incentives to ram breeders to cover the extra costs in either Inverdale ram breeding programme. As illustrated by McEwan *et al*., (1995), the potential financial rewards to the New Zealand sheep industry are substantial. Realisation of this potential will depend on the willingness of commercial sheep farmers currently operating relatively simple breeding systems with homebred replacements to adapt their flock structures to fit the systems described here.

## REFERENCES

Amer, P.R. 1998. Economic accounting of numbers of expressions and delays in sheep gnetic improvement. *New Zealand Journal of Agricultural Research* (In Submission).

Amer, P.R., McEwan, J.C., Dodds, K.G. and Davis, G.H., 1998. Economic values for ewe prolificacy and lamb survival in New Zealand sheep. *Livestock Production Science*. (In Submission).

Davis, G.H., McEwan, J.C., Fennessy, P.F., Dodds, K.G., and Farquar, P.A., 1991. Evidence for the presence of a major gene influencing ovulation rate on the X chromosome of sheep. *Biology of Reproduction* **44:**620-624.

McEwan, J.C., Davis, G.H., Fennessy, P.F. and Dodds, K.G., 1995. Industry use of the Inverdale gene (FecX). *Proceedings of the New Zealand Society of Animal Production,*Vol **55:**298-300.