THE INVERDALE PROLIFICACY GENE IN SHEEP

Introduction

As the list of references at the end of this contract shows, publications arising from research into the Inverdale gene are found in numerous journals and conference proceedings. This makes it difficult for farm advisors and practically impossible for farmers to access all of this information. The contract approach has enabled current knowledge on the Inverdale gene across a range of disciplines to be presented at a farmers' day within the annual conference of the NZSAP and subsequently published in the proceedings as a readily accessible reference.

The contract comprises seven papers from scientists covering different aspects of research into the Inverdale gene, and for the first time there are two papers from farmers with first hand experience of managing these prolific sheep. The scope of the papers allows readers unfamiliar with the Inverdale gene the opportunity to be informed on the implications of this gene in a single publication.

It is very appropriate that this collection of papers on the Inverdale gene is published in the proceeding of the NZSAP conference, as the first hint that this Romney family may have a major gene for prolificacy was contained in a paper I presented to the 1987 conference of the Society. The subsequent discovery that the gene is on the X-chromosome, homozygous females are infertile, and tumour-like structures develop on the ovaries of some homozygous ewes are all outlined in this contract together with current knowledge on ovarian characteristics, hormone profiles, genetic markers and the use of the gene in industry.

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Discovery of the Inverdale gene (FecX)

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ABSTRACT

Selection for ovulation rate in a screened prolific flock identified a prolific family of Romneys in 1984 that descended from one ewe, and progeny tests of her male descendants carried out from 1985 to 1990 indicated the presence of a major gene (Inverdale) on the X-chromosome. One copy of the gene increases ovulation rate by about 1.0 and litter size by about 0.6. However, research in 1991 found that ewes with two copies of the gene have small non-functional 'streak' ovaries and are infertile. Many of these infertile ewes develop tumour-like structures on their ovaries and these are currently the subject of intensive research.

In 1993 a prolific Romney flock in Tokoroa, with no known connection with A281, was also found to have the Inverdale gene. The place of the Inverdale gene in industry will be to increase prolificacy in ewe flocks mated to terminal sires, and a research programme has been established to identify a genetic marker for ram breeders.

Keywords: sheep; prolificacy; Inverdale gene; major gene.

SCREENED PROLIFIC EWE

In 1979 a high prolificacy flock was established at the Invermay Agricultural Centre, Mosgiel, by screening Romney, Coopworth and Perendale ewes from the national flock on the basis of a history of high litter sizes (Kelly *et al.*, 1983). Subsequent selection within breed was on ovulation rate, and in 1984 a prolific family of Romneys was identified that descended from a screened ewe (A281) from the property of Mr Derek Weir at Banks Peninsula (Davis *et al.*, 1987). A281 had 33 lambs in 11 lambings and had been purchased at the Addington saleyards as a two tooth in 1968. Apart from the fact that she came from a property at Albury in South Canterbury, nothing is known of her origin. By 1984, seven of her female descendants in the screened flock had a mean ovulation rate of 2.45 (SE = 0.15), and a flock of 30 descendants had an average litter size of 2.4 on the Banks Peninsula farm.

Ram progeny tests

Progeny tests of three grandsons of A281 bred at the Woodlands Research Station in Southland were carried out

from 1985 to 1989 and high ovulation rates in the daughters of one ram (84-81) indicated the presence of a major gene for prolificacy in this family (Davis *et al.*, 1988;1991b). One of these progeny tests also involved a great grandson of A281 sourced from the Banks Peninsula farm, and the high prolificacy of his daughters confirmed that A281 was the progenitor of the high prolificacy in this family. Rams known to carry the Booroola gene (FecB) were also included in the progeny tests, and comparisons between their daughters and the daughters of rams from the A281 family showed that the gene segregating in this family differed from the Booroola gene.

The inheritance of high ovulation rate in this family was consistent with a gene carried on the X-chromosome (Dodds *et al.*, 1995). In 1990, this hypothesis was tested in a large progeny test in Mr Arnold Gray's commercial flock at Tuatapere, involving six sons and five maternal grandsons of ram 84-81, each mated with 100 ewes. None of the sons, but three of the five grandsons had daughters with high ovulation rates which demonstrated that the major gene was carried on the X-chromosome, and it was subsequently named the Inverdale gene (Davis *et al.*,1991a).

Gene effect

Results from the Tuatapere flock showed that the effect of one copy of the Inverdale gene was to increase ovulation rate by about 1.0 and litter size by about 0.6 (Davis *et al.*, 1993). In contrast, ewes with one copy of the Booroola gene have ovulation rates increased by about 1.6 and litter size by about 0.9 (Piper *et al.*, 1985). The performance of Inverdale ewes under commercial conditions has continued to be monitored in the Tuatapere flock (Gray and Davis, 1995), and blood samples from progeny groups have been an important source of DNA used in the search for a genetic marker for the Inverdale gene.

Streak ovaries

In 1989 and 1990, four rams carrying the Inverdale gene ($FecX^{I/Y}$)were mated with ewes carrying one copy of the gene ($FecX^{I}/FecX^{+}$) in research flocks to determine the effect of the gene in daughters with two copies ($FecX^{I}/FecX^{I}$). On average, half of the daughters from these matings would have two copies of the gene and half would have one copy. When the ovaries of the 59 daughters were examined by laparoscopy in 1991 it was found that 48% had small non-functional 'streak' ovaries and were infertile (Davis *et al.*, 1992). The remaining ewes had ovulation rates consistent with carrying one copy of the gene. As previous progeny tests had shown that all females with one copy of the gene had fully functional ovaries, it was evident that the streak ovary condition was a characteristic of double copy ewes. There is now evidence from the 160 daughters of 12 $FecX^{I/Y}$ rams mated with $FecX^{I}/FecX^{+}$ ewes that females with two copies of the gene are infertile (Davis *et al.*, 1994).

There is normally a delay in establishing the prolificacy of a ram under progeny test, because his daughters must reach reproductive age before they can be evaluated. However, the streak ovary condition can be used in a simplified and accelerated progeny test to determine whether a young ram carries the Inverdale gene. The ram under test is mated as a lamb with single copy ewes and the daughters are examined for the presence or absence of streak ovaries. As one daughter with streak ovaries is sufficient to identify the ram as a carrier, only five daughters per ram are required to identify 97% of carrier rams. Because the streak ovary condition can be observed before puberty, females as young as two months of age can be examined by a laparoscope to determine whether the ovaries are normal or streak (Davis *et al.*, 1994). This enables a ram lamb to be mated in autumn and his daughters laparoscoped the following summer to allow his Inverdale genotype to be determined in advance of his mating as a two tooth. This technique has been successfully used in research flocks and the commercial flock at Tuatapere to identify carrier rams.

Continued laparoscopic observation of ewes from the Invermay flock with streak ovaries has shown that many develop tumour-like structures on their ovaries and these are currently the subject of intensive research (Braw-Tal *et al.*, 1993; McLeod *et al.*, 1993). This and other characteristics of the Inverdale gene also make it a useful research model.

Another source of the Inverdale gene

In 1993 the prolific Romney flock of Mr Mac Hanna at Tokoroa, with no known connection with the Banks Peninsula ewe, was also found to have the Inverdale gene (Hanna, 1995). The presence of the gene was confirmed using the streak ovary condition when a ram at Invermay, known to carry the Inverdale gene, was mated with six prolific ewes from the Tokoroa flock. Eight months later, the female progeny were examined by laparoscopy and some were found to have streak ovaries.

The first recorded instance of the streak ovary condition occurring in a commercial flock, apart from a progeny test situation, was in 1994 when the daughter of a ram and ewe that had both been bred in the Tokoroa flock was also found to have streak ovaries. This flock can be traced back for 29 years and no South Island sheep were introduced during that time. If the Banks Peninsula and Tokoroa flocks do have a common Inverdale ancestor, it goes back beyond 29 years and it is possible that the gene lies undetected in other sheep flocks in New Zealand.

The discovery of the Inverdale gene, and the subsequent identification of sheep carrying the gene, has relied on progeny testing to evaluate the reproductive performance of daughters. However, the successful use of the gene in industry depends on the identification of a genetic marker that can be used on young sheep in ram breeding flocks as a shortcut to reliably test for the Inverdale gene. Ram breeders could then have their sheep blood-tested to identify those known to carry the gene without the need for progeny testing. A genetic marker would also be a useful tool with which to screen other prolific flocks in industry that are suspected of carrying the Inverdale gene.