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Effect of the Inverdale gene (FecX) on fleece characteristics in Romney sheep

T. WULIJI, G.H. DAVIS, K.G. DODDS, R.N. ANDREWS, R. WHEELER AND P.R. TURNER

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

ABSTRACT

The effect of the Inverdale gene (FecX) on wool production traits was measured in a trial where Romney carrier rams (I) were crossed and backcrossed with high fleece weight-selected (HF) Romney ewes, and Romney non-carrier rams (+) with unselected (RC) Romney ewes. The trial generated 248 female progeny in five genotype subgroups: non-carrier (++)$^1/_2$RC and $^1/_4$RC; heterozygous (I+)$^1/_2$HF and $^1/_4$HF; and homozygous (II) $^1/_4$HF. The live weight, fleece weight, wool characteristics and reproductive performance of these genotype subgroups were compared, and from corresponding genotype subgroups of male progeny (n = 307) were also evaluated for early growth and fleece traits. No differences were found for birth, hogget shearing and two-tooth live weights among genotypes. Greasy fleece weight was significantly (P<0.05) higher for I+$^1/_2$HF ewes shorn as lambs (9%), hoggets (8%) and two-tooths (10%) compared with ++$^1/_2$RC. The important wool characteristics of yield, fibre diameter, bulk, staple length and staple crimp did not differ significantly between genotypes. The ovulation rate (combining subgroups with the same Inverdale genotype) was significantly (P<0.05) higher for I+ (2.3) than ++ (1.5) progeny (SED: 0.3). The results suggest that introgression of FecX^I into fleece weight selection flocks will improve prolificacy in these flocks while ensuring high fleece weight.

Keywords: Inverdale; FecX, crossbreeding; ovulation; fleece weight.

INTRODUCTION

The discovery of the Inverdale (FecX) major gene for prolificacy (Davis *et al.*, 1991) presents an opportunity to increase prolificacy in the sheep without hormonal manipulation. Inverdale ewes carrying a single copy of the FecX gene (I+) possess a different level of ovarian function, which primarily boosts the number of ovulations at each oestrous cycle (Davis *et al.*, 1991; McNatty *et al.*, 1995). The effect of one copy of FecX^I was estimated to increase the ovulation rate by 1.0 and litter size by 0.6 (Davis *et al.*, 1993). The location of FecX on the X-chromosome, its mode of inheritance, and its strategic use in industry have been discussed in detail (Davis *et al.*, 1995; Galloway *et al.*, 1995; Dodds *et al.*, 1995; McEwan *et al.*, 1995). However, there is no documentation on the effect of FecX on wool production performance and wool traits in fleece weight selected flocks. This trial was conducted to assess these effects by comparing progeny subgroups from matings of FecX carrier rams (I) with Romney high fleece weight selected ewes, and non-carrier rams (+) with unselected ewes.

MATERIALS AND METHODS

Animals

Mixed age ewes were from either Romney high fleece weight (HF) selected, or unselected control (RC) flocks, which had been established at Woodlands Research Station in 1985 (Hawker and Littlejohn, 1986). Progeny tested + and I rams were selected from an Inverdale flock (Davis *et al.*, 1991). Four different I sires were used each year, and were joined with 60, 80 and 85 HF ewes in 1991, 1992 and 1993 respectively. They were also backcrossed with 40 I+ 2-tooth ewes in 1993, and 85 I+ 2-tooth and 4-tooth ewes in 1994. Two + sires were used each year, and were joined with 40, 60 and 60 RC ewes in 1991, 1992 and 1993 respectively. They were also backcrossed with 30 ++ 2-tooth ewes in 1993, and 60 ++ 2-tooth and 4-tooth ewes in 1994. The trial generated 555 progeny in nine subgroups for fleece evaluation (Table 1). A feature of FecX inheritance is that it is sex-linked, hence the male progeny of an I ram and HF ewes are all +, and female progeny are all I+. When these I+ genotypes were mated to an I ram, their male progeny were either + or I (expected ratio 1:1); and female progeny either I+ or infertile homozygous (II) (expected ratio 1:1). The actual genotypes (+ or I) of these ram lambs were not determined because it would have required extensive progeny testing, but the genotypes (II or I+) of these ewe progeny were determined by laparoscopic observation of the ovaries at five months of age. All other genotypes could be determined by pedigree. The mating plan was a compromise because an alternative of mating HF(+) and RC(+) rams with I+ ewes would have resulted in I+ and ++ female progeny which could not be accurately assigned an Inverdale genotype on the basis of laparoscopic measurement as an overlap in individual ovulation rates. Within years, progeny of all genotypes were managed as a single flock.

Records and measurements

Progeny were born in their respective sire groups, ear tagged at birth and their pedigrees and birth ranks recorded. Birth (BWT), weaning (WWT), January (JWT), winter (WTT), spring (SWT) and two-tooth (TWT, 16 month old) live weights were recorded. Greasy fleece was weighed at shearing as lambs (LGF, 4 month old), hoggets (HGF, 12 month old) and two-tooths (TGF, 16 month old) excluding belly wool. A mid-side fleece sample was collected from each fleece at shearing and hogget clean fleece weight (HCF) was calculated using the dry yield (%) measurement. The 2-tooths were joined with rams in mid-April and ovulation rate (OR) was determined by laparoscopy 18 days after joining. The number of lambs born per ewe lambing (NLB) and number of lambs reared per ewe lambing (NLR) were recorded for two-tooth ewes. The back fat (BF) depth was measured with an ultrasonic scanner using the procedure described by McEwan *et al.* (1989). Wool characteristics were measured for mean fibre diameter (FD), core wool bulk (bulk), staple length (SL), staple strength (SS), the position of break by a ratio from the staple base to tip (POB), staple crimp (SC), and tristimulous colour as brightness (Y) and yellowness (Y-Z) as previously described by Wuliji *et al.* (1995).

Statistical analysis:

Data were analyzed by residual maximum likelihood (REML). Subgroup, year, sex, birth/rearing rank and age of dam were included as fixed effects, birth day as a covariate and sire as a random effect in the model. The sire variation was fixed as a proportion of the residual variation using previously established estimates for the traits. The models for BWT, WWT, JWT, SWT, LGF and HGF included the interaction between sex and year, as suggested by a preliminary investigation of two-factor interactions. The model for BF also included scanner operator as a fixed effect and live weight at scanning, nested within sex, as a covariate. Means are presented as least squares means from these models.

RESULTS AND DISCUSSION

Birth weight to hogget live weight, greasy fleece weight and back fat depth of the subgroups were compared within sex (Table 1). No significant live weight differences were found for ewe genotype groups except that WTT was significantly higher for I+$^{1}/_{2}$HF and ++$^{1}/_{2}$RC ($P<0.05$) compared with I+$^{1}/_{4}$HF. Live weights of ram subgroups were more variable with the +$^{1}/_{2}$HF group significantly ($P<0.05$) heavier than +$^{1}/_{2}$RC for BWT, WTT and SWT , and than +$^{1}/_{4}$RC for BWT, JWT and SWT. The I+$^{1}/_{2}$HF ewe group were significantly ($P<0.05$) higher than ++$^{1}/_{2}$RC for LGF (9%) and for HGF (8%). No significant subgroup difference was found in LGF for rams, but HGF was significantly ($P<0.01$) higher (26.8%) for +$^{1}/_{2}$HF than +$^{1}/_{2}$RC rams. There was no difference shown among the other subgroups. The ++$^{1}/_{2}$RC ewes were significantly fatter ($P<0.05$) than I+$^{1}/_{2}$HF and I+$^{1}/_{4}$HF ewes, but the BF of rams did not differ significantly between subgroups. Ewes were significantly ($P<0.01$) fatter than rams.

Two-tooth live weight, fleece weight and reproductive performance of ewes are presented in Table 2. The ewe TSW did not differ between subgroups but TGF remained significantly ($P<0.05$) higher (by 10-11%) for I+$^{1}/_{2}$HF than ++$^{1}/_{2}$RC and I+$^{1}/_{4}$HF. The OR was significantly ($P<0.05$) higher for I+ than ++ progeny being 2.3 and 1.5 (SED: 0.3) respectively, but there was no significant difference between the subgroups within these Inverdale genotypes. Similarly, NLB was significantly ($P<0.01$) higher by 0.64 for I+ than ++ progeny, but there was no significant difference between the subgroups within genotype. However, there was only a 0.11 advantage (not significant) in NLR for the combined I+ genotype over the ++ Romney controls.

Ewe hogget clean fleece weight and wool characteristics are shown in Table 3. The HCF was highest for I+$^{1}/_{2}$HF among the subgroups, being 6.4% higher (not significant) than ++$^{1}/_{2}$RC. Though differences were minor, SS and Y were lower while POB was higher ($P<0.05$) for I+$^{1}/_{2}$HF than ++$^{1}/_{2}$RC. For Y-Z, II$^{1}/_{4}$HF were significantly yellower ($P<0.05$) than ++$^{1}/_{2}$RC. No difference was found between subgroups for the wool characteristics of yield, FD, bulk, SC and SL, which should ensure that wool clips from flocks where FecX^{I} has been introgressed will re-

TABLE 1: Least square means of live weight (kg), greasy fleece weight (kg) and back fat depth (mm) comparing Inverdale x Romney high fleece weight selected or control line crosses (Born 1991-1994); trait names are given in the text.

Subgroup	No.	BWT	WWT	JWT	WTT	SWT	LGF	HGF	BF
Ewes									
++ $^{1}/_{2}$RC	55	3.7	18.8	25.8	33.9^{b}	32.6	1.28^{a}	2.33^{a}	2.93^{b}
++ $^{1}/_{4}$RC	39	3.9	18.4	24.4	31.3^{ab}	31.0	1.33^{ab}	2.26^{ab}	2.44^{ab}
I+ $^{1}/_{2}$HF	110	3.9	19.0	25.6	34.2^{b}	32.8	1.40^{b}	2.51^{b}	2.54^{a}
I+ $^{1}/_{4}$HF	30	3.5	18.7	23.7	30.3^{a}	30.5	1.30^{ab}	2.16^{a}	2.19^{a}
II $^{1}/_{4}$HF	14	3.8	18.5	23.7	32.5^{ab}	31.4	1.30^{ab}	2.32^{ab}	2.26^{ab}
Mean S.E.D.		0.3^{ns}	1.2^{ns}	0.3^{ns}	1.6	1.6^{ns}	0.08	0.13	0.35
Rams									
+$^{1}/_{2}$RC	64	4.0^{a}	20.1	26.7^{ab}	32.3^{a}	29.4^{a}	1.24	1.94^{a}	2.01
+$^{1}/_{2}$HF	147	4.3^{b}	20.6	29.0^{b}	36.3^{b}	34.7^{b}	1.40	2.46^{b}	1.61
+$^{1}/_{4}$RC	32	3.7^{a}	19.1	26.3^{a}	33.7^{ab}	31.3^{a}	1.32	2.28^{ab}	1.71
I or +$^{1}/_{4}$HF	64	3.9^{ab}	20.1	26.9^{ab}	35.2^{ab}	32.0^{ab}	1.26	2.23^{ab}	1.64
Mean S.E.D.		0.2	0.9^{ns}	1.4	1.8	1.7	0.09^{ns}	0.14	0.36^{ns}

^{abc}: within columns means bearing a different superscript differ at $P<0.05$; ^{ns}: not significant.

TABLE 2: Least square means for 16 month old shearing weight (kg), fleece weight (kg) and reproductive performance in the Inverdale crosses; trait names are given in the text.

Subgroup	TSW	TGF	OR	NLB	NLR
++$^1/_2$RC	49.7	2.47^a	1.35^a	1.46^a	1.29
++$^1/_4$RC	49.1	2.49^{ab}	1.66^{ab}	1.49^{ab}	0.90
I+$^1/_2$HF	49.5	2.72^b	2.33^b	2.09^b	1.08
I+$^1/_4$HF	46.7	2.44^a	2.28^b	2.14^{ab}	1.33
II $^1/_4$HF	48.3	2.67^{ab}	-	-	-
Mean S.E.D.	2.6^{ns}	0.15	0.41	0.33	0.35^{ns}

^{abc}: within columns means bearing a different superscript differ at P<0.05; ^{ns}: not significant.

main in the same processing categories as Romney wool.

Effects of sex, birth rearing ranks and age of dam were compared (data not shown). The effect of sex was highly significant (P<0.001) for BWT, WWT, JWT and significant for WTT (P<0.05) in favour of males; age of dam was significant (P<0.01) for BWT, WWT, JWT and LGF in favour of older dams (3+ years). A comparison of birth/rearing ranks showed that single births were significantly higher than multiple births for BWT, WWT, JWT, WTT, SWT and LGF (P<0.001). The magnitude of these effects agreed with previous studies in Romney sheep (Hawker *et al.*, 1988; Wuliji *et al.*, 1991).

The OR increase in I+ compared to ++ was similar to previous studies in Inverdales (Davis *et al.*, 1991; Davis *et al.*, 1993; McEwan *et al.*, 1992). Davis *et al.* (1991, 1993) found that OR was increased by 1.0 in I+ in the original Inverdale progeny tests. Similarly, McEwan *et al.* (1992) showed that OR measured prior to mating in two-tooth I+ was 0.98 higher than in ++ ewes. The current trial shows I+ types increased by 0.62 and 0.98 increases in OR compared with ++$^1/_4$RC and ++$^1/_2$RC. The NLB difference between I+ genotypes and the ++ Romney controls was not sustained in the later measurement of NLR. The advantage of 0.8 in OR and 0.64 in NLB was reduced to only 0.11 in NLR. We speculate several factors for this. Firstly, the ewes compared in the genotypes were mostly two-tooths which probably contributed to a lower survival rate of multiple births; secondly, the lower mothering and lactation capability of younger ewes may have disadvantaged the multiple births; and thirdly, the common lambing and rearing management regimen at Woodlands Research Station could also have disadvantaged the high prolificacy flocks. The problem of poor lamb survival in prolific flocks was also observed in a previous study (McEwan *et al.*, 1992).

FecX has shown no effect on any live weight, fleece weight or wool characteristic in the trial. McEwan *et al.* (1992) found no difference between I+ and ++ for live weight and greasy fleece weight. A similar comparison between genotypes of I+ and ++ ewe progeny showed no significant differences for live weight and greasy fleece weight at 1.5 years old (Davis *et al.*, 1993). Davis *et al.* (1993) estimated an extra 0.17 lambs tailed per ewe mated in I+ than ++ ewes. A slight lift in live weight of the progeny of Inverdale x HF cross and their moderate fleece weight increase (10%) are benefits of introducing HF genes into the I+ genotype. This was also demonstrated by the decline in these traits with decreasing HF blood (i.e. to $^1/_4$HF).

Hormonal assays in Inverdale ewes (McLeod *et al.*, 1997) indicate that the hormonal profile screening at puberty will provide a reliable discrimination between I+ and II Inverdale genotypes replacing the requirement of skilled laparoscopic observations in ram breeding flocks. DNA marker linkage tests to distinguish ambiguous Inverdale genotypes are also being developed (Galloway *et al.*, 1995). These initiatives promise to provide a simple, fast and accurate FecX genotype test in sheep at an early age, allowing selection for carrier genotypes and their introgression into the industry on a large scale, combined with important production traits, such as meat, milk and wool.

Conclusion and Recommendations

The results suggest that introgression of FecX^I into a fleece weight selection programme will improve prolificacy in these flocks and provide high fleece weight I sires for the sheep industry. However, it is important to recognize and adopt a sustainable lambing and rearing management scheme to be able to benefit from a high number of lambs reared and weaned per ewe lambed as a result of the high ovulation and lambing rate of highly prolific ewes.

TABLE 3: Least square means for clean fleece weight and wool characteristics for Inverdale genotype / subgroups (ewe hoggets); trait names are given in the text.

Subgroup	HCF (kg)	Yield (%)	FD (µm)	Bulk (cm^3/g)	SC (5cm)	SL (mm)	SS (Nktex)	POB (%)	Y	Y-Z
++ $^1/_2$RC	1.56^{ab}	68.1	34.8	24.6	6.3	117	21.0^b	60.6^a	62.5^b	5.8a
++ $^1/_4$RC	1.54^{ab}	68.1	34.1	25.2	7.2	119	22.4^{ab}	63.6^{ab}	62.0^{ab}	5.8ab
I+ $^1/_2$HF	1.66^b	66.5	34.3	24.6	7.1	115	18.2^a	65.2^b	62.0^a	6.0ab
I+ $^1/_4$HF	1.40^a	66.6	34.3	24.1	7.4	109	19.5^{ab}	63.0^{ab}	61.2^a	6.2ab
II $^1/_4$HF	1.56^{ab}	68.1	34.2	24.4	7.3	108	20.1^{ab}	66.4^{ab}	61.7^{ab}	6.5b
Mean S.E.D.	0.12	1.5^{ns}	1.0^{ns}	0.9^{ns}	0.8^{ns}	6^{ns}	2.5	4.1	0.6	0.3

^{abc}: within columns means bear a different superscript differ at P<0.05; ^{ns}: not significant.

Such a scheme may include pregnancy scanning of ewes, preferential feeding for multiple bearing ewes, sheltered lambing, and high level feeding of the multiple rearing ewes during lactation.

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