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Comparison of growth, hogget fleece weight and reproductive traits of three sheep breeds from a flock selected for prolificacy and a Romney control flock

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ABSTRACT

The production of the Woodlands high prolificacy flocks was compared to industry control animals. Effects of the Inverdale gene (FecX^I), which was present in the high prolificacy Romney flock, were also examined.

Inverdale genotype (++ vs I+) had no significant influence on any liveweight or fleece weight examined so both genotypes were combined. Relative to a Romney industry control line, the three lines derived from screening for high prolificacy with subsequent selection on ovulation rate (Romneys, Perendales and Coopworths) had significantly heavier ewe hogget (12 month) liveweights after adjustment for non-genetic factors with weights of 32.9 (100), 38.7 (118), 39.1 (119) and 41.4 (126) kilograms (percentage relative to Romney controls). Hogget fleece weights (kg) were 2.38 (100), 2.69 (113), 2.29 (96) and 2.89 (121) respectively.

The Inverdale gene had a large effect on reproductive traits, increasing ovulation rate by 0.98 and increasing litter size by 0.31. However, this was negated by a lower survival rate in the progeny resulting in little change in net reproductive rate. Relative to Romney industry controls the high prolificacy Romney (++), Perendale and Coopworth flocks all had higher ovulation rates which translated into heavier weight of lamb weaned per ewe mated with weights of 16.8 (100), 20.9 (124), 21.9 (130), and 26.0 (155) kilograms respectively. The benefits were still substantial even after consideration of wool clipped and correction for ewe liveweight. The flocks represent a valuable genetic resource for improvement of the sheep industry.

Keywords Sheep, breed, Coopworth, Perendale, Romney, prolificacy, liveweight, fleece weight, reproduction.

INTRODUCTION

Low reproductive rate of traditional New Zealand sheep breeds is a major limitation to improvement of New Zealand farming productivity. One approach to improving prolificacy is to screen major breeds for animals with a history of exceptional prolificacy. The methodology of such a nationwide program was described by Kelly *et al.*, (1983). This program established flocks of high prolificacy Romney, Perendale and Coopworths, which are presently grazed at Woodlands Research Station in Southland.

After an initial period of expansion, the flocks were closed and subsequent selection has been for increased ovulation rate (Davis *et al.*, 1987). No comparable control flocks were established at the initiation of the project, so definitive information on the improvement in prolificacy or correlated changes in other productive traits, relative to industry animals were not available. Therefore, to overcome this problem and provide more accurate information on the productive benefits of the high prolificacy lines at Woodlands, the Romney control line from the Romney selection project (Tait 1983) was used as a reference with which to compare growth, carcass traits, wool production and the reproductive parameters of the selected animals. This flock is representative of the New Zealand Romney industry flock in 1969.

Results from the high prolificacy flocks for growth and carcass traits in ram lambs (McEwan *et al.*, 1990), showed that relative to Romney industry controls, all high prolificacy flocks had marked improvements in adjusted carcass weights while differences in fat and muscle depths were small and generally favorable. This report extends the comparison to include liveweights, fleece weights, ultrasonic fat depths and reproductive characters from the female progeny. A subset of these data has been used to estimate genetic parameters for ultrasonic measurements (McEwan *et al.*, 1991).

Recently, a sex linked gene has been identified as being present within the Romney high prolificacy flock (Davis *et al.*, 1988, 1991, 1992a, 1992b). This gene (FecX^I; Inverdale) has been traced to one donated ewe (A281), which prior to entering the screened flock had produced 33 lambs in 11 lambings. Based on progeny test results in external flocks, the Inverdale gene has been estimated to increase ovulation rate by 1.0 in the heterozygote (I+), but cause ovarian hypoplasia, with resulting sterility in homozygotes (II). The effects of the gene were examined within the high prolificacy Romney flock.

METHODS

The trial was conducted using the 1985 to 1989 born ewe lamb progeny. Dams in the high prolificacy experiment consisted of descendants from original screened ewes, although a small proportion of screened ewes were still present. The programme involves three breeds, namely Romneys (HPR), Perendales (HPP) and Coopworths (HPC). Each year the high prolificacy dams were single sire mated to one of 5 rams from their own flock for 34 days. Rams were selected on the basis of their dam's ovulation rate (Davis *et al.*, 1987). This was followed by mob mating to blackface rams for an additional 17 days. Romney control line (RC) dams were grazed and managed as part of the same flock. They were derived from surplus animals from the control line of the separately managed Romney selection experiment (Tait, 1983) The RC dams were single sire mated to rams chosen at random

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(5 per year) from the control line of the Romney selection experiment. Progeny from 115 sires are present in the analysis.

The number of progeny with records ranged between 2563 (birth) and 1538 (27 months of age) with most of the decline in numbers occurring between birth and weaning. This reduction was caused by deaths prior to weaning, and also culling at weaning of progeny from two tooths, which were culled themselves, because of low ovulation rates. A Coopworth control line, derived from the HPC was also present and included in the analysis to increase the precision of fixed effects estimates. Their results are not presented as they differ little from the HPC flock. During mating at 18 months of age 343 HPR animals were present (67 I+, 255 ++ and 21 of unknown genotype which were excluded during analysis of reproductive traits), 374 HPP, 538 HPC and 111 RC.

Trial dams were run together except during joining, when they were grazed on similarly managed pastures, and after lambing where they and their lambs were allocated by lambing date to four to six similarly managed pre-weaning grazing groups. After weaning the ewe lambs were grazed together on pasture and managed as one mob. At 16 months of age they joined the adult ewe mob and were managed as described for their dams. Belly wool was not included in either hogget fleece weight (12 months of age; 8 months wool) or post weaning fleece weight (27 months of age; 10.5 months wool). Ultrasonic C measurements were undertaken at 8 to 9 months of age with an AIDD or Delphi scanner as described by McEwan *et al.*, (1989). Ovulation rate was measured twice by laparoscopy, once within 2 days prior to joining and again 19 to 23 days later.

Data were analysed by residual maximum likelihood procedures (Thompson, 1977) treating genotype, birth/rearing rank and year born as fixed effects, sires within genotype as a random effect, birth date as a linear covariate, and dam age as a linear and quadratic covariate, for liveweight and fleece weights up to 18 months of age. Liveweights and fleece weights, after 18 months of age, also included the effect of number of lambs born and reared by the animal itself (rearing status). Ultrasonic C and its covariate liveweight were log transformed and the effect of operator was included. First order interactions were included in initial models and subsequently eliminated where the effects were non-significant. Best linear unbiased estimates were calculated for the traits, adjusted to the covariate means. Sire variation within genotype was used to test significance of genotypic differences.

RESULTS

Dam age, birth/rearing rank, year born and birth day, and rearing status, all had significant effects on the liveweights and fleece weights recorded. The absolute size of these effects were similar to those reported from other data sets (Baker *et al.*, 1979). Few first order interactions were significant and these resulted from interactions of fixed effects with year born. In no case were there significant interactions with genotype. Most traits had significant sire variation within genotype and these results will be presented in detail elsewhere. Genotype comparisons presented in Table 1 were obtained from the residual models which included main effects and interactions where they were significant.

None of the traits in Table 1 had significantly different estimates for the Inverdale genotypes within the HPR and so they were combined. HPR were 3 percent heavier at birth than RC (NS), and this increased to 18 percent at 12 months of age (P<0.01) and then declined to 11 percent (P<0.01) by 27 months of age. The latter decline was due to an increase in the RC liveweights relative to the HPR after 12 months of age. HPC were heavier at all ages than RC being 11 percent heavier at birth (P<0.01) rising to a maximum of 26 percent at 12 months of age and declining to 14 percent by 27 months of age. Relative to HPR, the HPC are 5 to 7 percent heavier at all ages (P<0.05 to P<0.01) except at 27 months of age, where they are 2 percent heavier (NS). HPP liveweights are generally intermediate to those of the HPR and HPC. In all cases they were significantly heavier than RC.

TABLE 1 Genotype estimates for liveweights, fleece weights and liveweight-adjusted ultrasonic fat depth[1]

	High Prolificacy			Control	Average
	Romney	Perendale	Coopworth	Romney	SED
Liveweights (kg)					
Birth[2]	4.10	4.16	4.43	3.99	0.069
Weaning[2]	18.9	19.7	20.5	17.3	0.29
8 months	36.5	36.6	38.4	31.8	0.50
12 months	38.7	39.1	41.4	32.9	0.53
18 months	56.0	57.2	60.1	49.1	0.72
27 months[3]	56.7	55.6	57.8	51.1	0.80
Fleece weights (kg)					
12 months	2.69	2.29	2.89	2.38	0.047
27 months[3]	3.53	2.80	3.46	3.11	0.071
Ultrasonic fat depth (mm)[4]					
C	3.44	3.79	4.44	4.54	0.135

[1] Adjusted for year born, birth/rearing rank, age of dam and birthdate
[2] Also adjusted for significant interactions between age of dam and birthdate within year born
[3] Also adjusted for significant rearing status effect
[4] Derived from a logarithmic model including year born, birth/rearing rank, age of dam, birthdate, logarithm of liveweight at scanning, and operator and the interactions of operator and liveweight with year born.

Hogget fleece weights showed marked differences between the genotypes with HPR having 13 percent heavier fleeces than the RC (P<0.01). Corresponding figures for the HPP and HPC were 4 percent lighter and 21 percent heavier respectively. However, when ranked on a per unit liveweight basis (12 months) RC was the highest at 72.3 gm fleece per kg liveweight (100) compared to slightly lower values for HPR and HPC at 69.5 (96) and 69.8 (97) while HPP again ranked lowest at 58.5 (81). Fleece weight at 27 months of age showed similar rankings to hogget fleece weight.

The ultrasonic C fat depth, adjusted for liveweight, differed significantly between the genotypes. Relative to RC sheep the HPC had 98 percent of the fat depth, but HPR and HPP were leaner with 75 and 83 percent of the fat depth respectively.

The genotype estimates for reproductive traits and overall productivity are presented in Table 2. As expected the Inverdale gene had significant effects on some reproductive components, and therefore they have been tabulated separately (Note: that when one trait in Table 2 can be derived as a multiplicative function of several others listed in the table, this function of the genotype estimates is not exactly equal to the genotype estimates of the function and is a result of the analytical technique used).

Generally, the differences in ovulation rate between high prolificacy genotypes and RC were slightly higher for the measurement ending the first cycle, but the relative rankings were unchanged. At the second measurement the HPR (++) genotype had a 0.45 higher ovulation rate than the RC while the HPR (I+)

was 1.43 higher than the RC and 0.98 higher than the (++) genotype (P<0.01 for all differences). The HPP was very similar to the HPR (++) genotype while the HPC was intermediate to the HPR genotypes and 0.73 of an ovulation higher than the RC (P<0.01).

TABLE 2 Genotype estimates for reproductive traits and productivity[1]

	Romney ++	Romney +	High Prolificacy Perendale	High Prolificacy Coopworth	Romney control	Avge SED[2]
Ovulation rate						
Prior to mating	1.69	2.60	1.64	2.06	1.44	0.070
First cycle	1.84	2.82	1.80	2.12	1.39	0.060
Reproduction						
EPL/EM	0.96	0.99	0.97	0.97	0.94	0.015
EL/EPL	0.91	0.92	0.94	0.95	0.89	0.024
LB/EL	1.64	1.95	1.56	1.87	1.25	0.058
LW/LB	0.75	0.59	0.80	0.75	0.83	0.039
LW/EM	1.13	1.07	1.16	1.35	0.92	0.070
Productivity estimates						
WTLW/EM[3]	20.9	17.1	21.9	26.0	16.8	1.44
Productivity[4]	37.9	33.2	35.2	42.5	31.9	1.52
Productivity /kg ewe liveweight	0.666	0.600	0.608	0.703	0.635	0.0248

[1] Adjusted for year born, age of dam, and birth date. Abbreviations: EM, ewes mated; EPL, ewes present at lambing; LW, lambs weaned; EL, ewes lambed; LB, lambs born; WTLW, weight of lamb weaned.

[2] Between (++) genotypes; multiply by 1.5 for comparisons with the I+ genotype

[3] Weight of lamb weaned per ewe mated adjusted for year born, dam age, birth date (within year born) and presence or absence of the Inverdale gene, but not birth/rearing rank

[4] Productivity =(weight of lamb weaned + 4 x annual ewe fleece weight) per ewe mated

Ewe survival rates (EPL/EM) were similar among the high prolificacy lines, but somewhat lower in the RC line, however, this difference was not significant. The percentage of surviving ewes that lambed (EL/EPL), separated into three groups with RC having the lowest values, the HPR genotypes having similar and intermediate values and the HPP and HPC genotypes the highest values. Only the difference between RC and HPC groups achieved significance (P<0.05). Prolificacy (LB/EL) reflected differences in ovulation rates between the genotypes although the magnitude of differences were reduced. Lamb survival (LW/LB) did not differ significantly between genotypes, except for the HPR (I+) genotype which was significantly lower than the other groups. Examination of lamb survival within birth ranks showed that the difference between the Inverdale and other genotypes for survival was not solely a reflection of differences in litter size and their distribution, with HPR (I+) singles having a significantly lower survival rate than equivalent HPR (++) animals (0.68 vs 0.89; P<0.05). The HPR (I+) also had the lowest survival in twin births (0.67) but the differences were not significant. Differences between other genotypes were were small and non-significant.

The higher ovulation rates and subsequent litter sizes more than compensated for the slight decrease in survival of the high prolificacy flocks, resulting in more lambs weaned per ewe mated relative to the RC. However, in the HPR (I+) flock the increased ovulation rate was negated by higher embryonic loss and decreased survival of the offspring relative to the HPR (++) flock, resulting in a slightly reduced lambing percentage for animals carrying the Inverdale gene.

Estimates of lamb production were obtained by comparing, the weight of lamb weaned per ewe mated. This trait combines the growth propensity of the lamb with reproductive efficiency and lactational ability of the ewe. It also includes the growth penalties associated with higher birth ranks in more prolific strains. The HPR (++) produced 24 percent more lamb weight weaned per ewe mated (P<0.05) than RC and suggests that the screening for prolificacy has increased the amount of saleable lamb for slaughter. Corresponding figures for HPP and HPC were 30 percent and 55 percent extra production (P<0.01) respectively. In contrast, the advantage of the HPR (I+) in prolificacy was negated by problems with survival and the low weaning weights of high birth rank litters, resulting in little change relative to the RC.

Productivity of the various genotypes was estimated by adding the weight of lambs the ewe weaned to four times the fleece weight clipped (adjusted to 12 months production). This provides an estimate of the economic value of these genotypes in the New Zealand marketplace. The HPR (++) genotype was 19 percent more productive than the RC. Corresponding figures for the HPR(I+), HPP and HPC genotypes were 4, 10 and 33 percent higher respectively. When expressed on a per unit liveweight (27 month) HPC animals were still the most productive genotype, 11 percent higher than the RC (P<0.05), while HPR (++) were 5 percent superior than the RC (NS).

DISCUSSION

The value of the nationwide screening for prolificacy is best examined by a comparison of the differences between the HPR and RC genotypes and secondly by comparisons between the three high prolificacy strains. The validity of using the RC line to compare the results of screening for prolificacy was examined by McEwan *et al.*, (1990) and found to be reasonable with evidence suggesting that they were similar to "traditional" Romneys at the time the screening procedure was undertaken in 1979 and 1980.

The comparison between the two Romney lines (Table 1) suggested that screening for high prolificacy has resulted in improved growth rate. The differences were similar to those observed in the male lambs (McEwan *et al.*, 1990), being small at birth and increasing post weaning. However, unlike the earlier study, comparisons were also available at older ages and these suggested that the magnitude of the differences declined after 1 year of age. This suggests that screening for prolificacy may have altered the pattern of growth to maturity with the HPR more rapidly approaching their mature weight. This change, if true, has beneficial effects on productivity as HPR progeny at normal slaughter ages would be heavier than expected for their mature size. Similar relative changes in the growth curve are also present in the HPC and the HPP genotypes. The relative ranking between the HPR, HPP and HPC genotypes is similar to reported "breed" differences reviewed by McEwan *et al.*, (1990). The Inverdale genotype had no significant effect on liveweight and this result is in accord with progeny test results from a separate trial (Davis *et al.*, 1992a).

Fleece production has not previously been reported for this experiment. The heavier fleeces in the HPR relative to the RC genotype appears to be mediated solely by an increase in liveweight, but as slight negative genetic correlations are often quoted between prolificacy and fleece weight (Morris, 1980) the expected change would be negative. The relative rankings between the HPP and HPR in wool production were similar to other reports (Clarke *et al.*, 1982; Sumner and Scott 1990; reviewed by McEwan *et al.*, 1985) where the breeds were compared. The HPC had higher wool production than the HPR as hoggets and similar wool production as two year olds in accordance with Andrews *et al.*, (1990) and Baker *et al.*, (1987), but higher than expected by Clarke *et al.*, (1982) and Sumner and Scott (1990). Inverdale genotype had no significant effect on fleece weights at either 12 or 27 months of age agreeing with progeny test results from a separate trial (Davis *et al.*, 1992a).

Ultrasonic fat depths were lower in the screened HPR animals than the RC suggesting that the screening for prolificacy has resulted in animals more in accord with consumer desires (Wood, 1982). These results support observations by McEwan *et al.*, (1984; 1989) in the Romney selection experiment where similar changes were observed. An increase in ovulation rate has also been observed after selection for reduced fat depth in the Invermay Coopworth lean/fat selection experiment (P.F. Fennessy pers. comm.). The previous report examining differences between carcass traits in male lambs (McEwan *et al.*, 1990) was complicated by the fact that different slopes between fat depth and liveweight were detected between the genotypes, but comparison at the mean carcass weight provided similar relative rankings. No significant differences were observed between the Inverdale genotypes. In summary, the results provide further evidence that the genetic correlation between prolificacy and backfat depth is negative and thus, favorable in economic terms.

The estimates of ovulation rate and litter size for the HPR++, HPP and HPC were similar (as were their liveweights) to the report of Davis *et al.*, (1987) for ewes mated at 1.5 years of age and as expected had markedly higher ovulation rate and litter sizes than the RC. Based on the data from Clarke *et al.*, (1982), Davis *et al.*, (1987) predicted the screening process had resulted in an increase of 0.31 in litter size of the HPR flock. The difference observed between the RC and the HPR (++) here was slightly larger than the previous estimate at 0.39. This information strongly suggests that the screening procedure and subsequent selection have been successful.

The screening procedure used in this programme also resulted in the identification of the sex linked Inverdale gene (Davis *et al.*, 1988, 1991). Using a combination of individual records and parentage records it was possible to identify most of the HPR genotypes in the flock. As expected the HPR (I+) had higher ovulation rates and litter sizes then the HPR (++). The estimates of the magnitude of its effect on ovulation rate were almost identical to those of Davis *et al.*, (1991). However, the resulting litter size difference estimate of 0.31 is markedly lower than that obtained from other progeny tests (Davis *et al.*, 1988, 1992a) which ranged between 0.58 and 0.80. These differences cannot be accounted for by differences in the ovulation rates of the base flocks as these were similar in all trials.

The significantly lower lamb survival after adjustment for litter size distribution in the HPR (I+) flock cannot be readily explained, particularly when other comparisons have found no such difference (Davis *et al.*, 1992a). More extensive investigations of the data could not identify any alternative explanation. The lamb survival rate in these flocks was lower than that generally observed (Baker *et al.*, 1987) due to extremely adverse environmental conditions in the 1987 lambing season, which depressed lamb survival to 66 percent overall. Resolution of the differences in lamb survival between the Inverdale genotypes awaits larger scale experiments, but these results may be atypical.

For industry acceptance net animal productivity needs to be increased by the screening and selection procedure. This has been amply demonstrated by the results presented. The direct comparison of productivity between the HPR (++) and the RC genotypes suggests an increase of 19 percent while the HPC is the most productive of all genotypes examined with a 33 percent better productivity than the RC. Recently, Baker *et al.*, (1987) published the results of a comprehensive study examining productivity of New Zealand industry breed "strains." The most extreme Romney genotypes were estimated at some 16 percent more productive than industry Romneys and the most extreme Coopworth genotype at 40 percent more productive than the industry Romney flock. The results observed in this study are of a similar magnitude and suggest that the New Zealand sheep industry could markedly increase its efficiency of production if rams from these identified sources were used more widely.

CONCLUSION

Comparison of the HPR(++), HPP and HPC genotypes with the RC suggests that improvements have been made in growth rate, wool production, leanness and weaning percentage. This has resulted in markedly improved productivity and these improvements, although reduced, are still present after adjustment for ewe liveweight. The improvements are similar in magnitude to the most extreme previous estimates for within breed "strains" and represent a valuable genetic resource for the New Zealand sheep industry. The productivity of animals heterozygous for the Inverdale gene was compromised by the lower than expected improvement in number of lambs born and the low survival rate of their progeny. These results conflict with other studies and further investigation is needed.

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