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Production and characteristics of wool from the hogget progeny of sheep intensively screened for fleece weight

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ABSTRACT

A high fleece weight Romney ewe flock was established by selecting the top 0.6% on greasy weight (GFW) from 32,000 hoggets (average selection differential 40%). These ewes were mated in 1985 and 1986 by Romney rams with high positive deviations for GFW (selection differentials 48% in 1985 and 57% in 1986). Relative to random progeny, the high fleece weight progeny born in 1985 and 1986 had 0.66 kg (28%) and 0.36 kg (12%) higher mean GFWs, respectively. Estimates of realised heritability were 0.45 and 0.22 for the 1985 and 1986 born hoggets, respectively.

Two sires used in 1985 had progeny distributions for GFW consistent with their having 1 copy of a single gene for GFW with an additive effect of approximately 1 kg. The single gene hypothesis is being examined by further progeny testing.

From birth to hogget shearing the high fleece weight hoggets had a significantly higher live weight than the control hoggets. Fleeces from the high fleece weight and control hoggets did not differ in yield or brightness. The high fleece weight hoggets had greater staple length, fibre diameter and staple strength with lower bulk and greater yellowness.

Estimates of the heritability of live weight, fleece weight and wool characteristics agreed with published estimates, as did estimated genetic correlations between GFW and other characteristics. The heritability of brightness was low.

Keywords Romney; selection; screening; hoggets; high fleece weight; segregation; fibre characteristics; staple strength.

INTRODUCTION

Selection for fleece weight from a random base population typically gives annual rates of response of 1 to 2% (McGuirk, 1983; Blair *et al.*, 1985; Johnson and Dobbie, 1987). There is however little information on responses following intensive initial screening for high fleece weight. Rates of response may be greater or less in the latter situation, depending on the number of genes involved and whether the response is consistent with the normal additive model of inheritance.

Hawker and Littlejohn (1986) described the establishment of a high fleece weight Romney flock at Woodlands Research Station by screening ewe hoggets from industry on greasy fleece weight (GFW). The present paper outlines the productivity of the progeny of the screened high fleece weight and random ewes and rams.

MATERIALS AND METHODS

Design and Animals

Establishment of the ewe flock was described by Hawker and Littlejohn (1986). The average selection differential of the screened high fleece weight flock was 3.1 standard deviation units, equivalent to 1.1 kg or 40%.

High fleece weight rams were obtained by screening the 2-tooth selection lists of ram breeders with 400 or more Romney ewes recorded on Sheeplan. There were approximately 5,000 and 20,000 rams screened in 1984 and 1985, respectively. In each year the 10 rams with the largest positive deviations for hogget fleece weight were selected. For the control flock a second ram was randomly selected from each breeder who contributed a high fleece weight ram. The mean selection differentials were +3.8 standard deviation units (1.7 kg or 48%) in 1984 and +4.5 standard deviation units (2.0 kg or 57%) in 1985.

In April 1985 and April 1986 the 10 high fleece weight and 10 control rams obtained in 1984 and 1985, respectively, were single-sire joined for 34 d to the respective high fleece weight ewes (20 per ram) and control ewes (10 per ram).

Measurements

The pedigree, birth weight, birth date and birth/rearing rank of each lamb were recorded. The lambs were weaned in December at approximately 80 days of age. They were shorn in late January. Live weight was recorded at weaning, in March (6 months of age), June (9 months) and at hogget shearing on 1 October (12 months). Ultrasonic back fat thickness was measured using a Delphi back fat meter (Delphi Industries Ltd., Auckland) in May or June and adjusted for live weight at scanning.

A midside patch was clipped on each hogget in late March, in mid June, and in late September. At hogget shearing greasy fleece weight was recorded and a midside sample collected. Yield, clean fleece weight (CFW), clean patch weight and clean dry wool growth in each period of measurement were determined by the methods detailed by Hawker and Thompson (1987). From the maximum and minimum wool growth rates the seasonal amplitude was calculated as 2 x (MAX-MIN)/(MAX+MIN) and expressed as a percentage.

Wool characteristics measured on the fleece samples were staple length, mean fibre diameter by sonic fineness tester (Andrews *et al.*, 1987), staple strength and position of break by Agritest Staple Breaker (3 staples per sheep), brightness and yellowness (Bigham *et al.*, 1984b), and loose wool bulk and resilience (Bigham *et al.*, 1984a). Bulk and resilience were highly correlated (r = 0.98) and had similar heritabilities so only bulk values are reported. Fibre volume was calculated from the staple length and fibre diameter results.

Statistical Analyses

The data were analysed by residual maximum likelihood (REML) procedures. Initial models fitted included year born, sex, birth/rearing rank, birth date, sire, farm of origin of the dam, selection line and 2 factor interactions. For each variable non-significant interactions were eliminated from the final model fitted. The experimental structure was a split plot design and appropriate error terms were used to test the significance of the various factors and interactions. In particular the selection line differences were tested using the between sire variation and degrees of freedom.

Paternal half-sib estimates of heritability and genetic correlations, and appropriate standard errors, were calculated using methods described by Becker (1985). Realised heritabilities and genetic correlations were calculated using methods outlined by Turner and Young (1969).

Most of the tests devised to detect single genes are imprecise unless the effects of the gene are large. In this experiment the deliberate selection of extreme individuals, especially the rams, enhanced the chances of locating single genes. In addition, the mating structure facilitated the use of a more specific and sensitive test, albeit at the expense of some assumptions. After correction for environmental effects, the within sire progeny distributions were tested for the presence of a single gene of additive effect. This test assumes that any sire would carry only 1 copy of such a gene. The progeny with and without the gene for the trait would have normal distributions with the same variance but with different means, μ_1 and μ_2, respectively. Therefore, the predicted progeny distribution (A) would be

$$A = ½\,(N(\mu_1, \sigma^2) + N(\mu_2, \sigma^2))$$

If there is no single gene $\mu_1 = \mu_2$ and the predicted progeny distribution would be $N(\mu, \sigma^2)$ where $\mu = \mu_1 = \mu_2$. If a single gene is indicated, its effect is estimated as $\hat{\mu}_2 - \hat{\mu}_1$.

RESULTS AND DISCUSSION

Environmental Effects

Year of birth and sex had significant effects on most variables. These effects are not discussed further unless there were significant interactions with selection line. Birth/rearing rank and birth date significantly affected most live weight and wool production measurements. Their effects on weaning weight, live weight at 12 months of age, lamb fleece weight and GFW are tabulated in Table 1. The differences in live weight and wool production between hoggets born and reared as twins or singles are similar to previous estimates (Baker *et al.*, 1974; Elliott *et al.*, 1978). Though the effects of birth date on wool production in the 3 studies are similar, the effects on live weight are greater in the present study.

TABLE 1 Effect (± standard error) and significance of birth/rearing rank and birth date on wool production and live weight. Of the 566 progeny, 254 were born in 1985 and 312 in 1986; 276 were ewe and 290 ram hoggets; 179 and 387 were in the control and high lines, respectively. The number of progeny per farm of origin of the dams varied from 16 (9 ewes represented) to 290 (163 ewes represented). The results presented were obtained from a REML model which adjusted, where appropriate, for year of birth, sex, birth/rearing rank, birth date, farm of origin of the dam, selection line, sire and (if significant) interactions between sex and selection line, and year and selection line.

Variable	Birth/rearing rank: Single/ single	Twin/ single[1]	Twin/ twin[1]	Regression on birth date (kg/d)
Number of animals	192	37	337	
Lamb fleece weight (kg)	1.24	-0.11 ± 0.04***	-0.31 ± 0.02***	-0.010 ± 0.002***
Hogget GFW (kg)	3.04	-0.32 ± 0.09***	-0.17 ± 0.05**	-0.013 ± 0.01***
Weaning weight (kg)	25.6	-2.8 ± 0.6***	-5.1 ± 0.3***	-0.250 ± 0.036***
Hogget live weight (kg)	40.3	-4.2 ± 1.0***	-3.0 ± 0.5***	-0.131 ± 0.065*

[1] Deviation from single born and reared

As expected, the birth date effects and the differences between animals born and reared as singles or twins decreased with age, providing evidence for compensatory growth. Surprisingly, there were larger differences for hoggets born as twins but reared as singles and these differences increased with age (Table 1). The relatively low productivity of the hoggets in this category may have been genetically determined rather than an environmental effect. Neither birth/rearing rank nor birth date significantly affected any wool characteristic.

Farm Effects

The farm from which the dams originated had a significant effect for a number of variables. The maximum relative differences between the farms (compared to the mean) were 12% for birth weight, 14% for weaning weight and between 8 and 14% for wool growth, lamb and hogget fleece weight and bulk.

Production of High Fleece Weight and Control Hoggets

Best linear unbiased estimates and deviations are shown in Table 2. On average the high fleece weight line was 6 to 8% heavier from birth to 12 months of age. Unlike GFW (mentioned later), there was no significant interaction between sex and selection line for any live weight. Similarly, interactions between year of birth and selection line were not significant for live weight. The selection lines did not differ significantly in live weight adjusted ultrasonic back fat thickness.

Mean clean wool yield (%) for the March, June and September patch samples was 76 ± 0.1 (SEM), 68 ± 0.2% and 62 ± 0.2% respectively. This pronounced seasonal trend indicates that the seasonal pattern of wool growth would be less pronounced if expressed on a greasy (amplitude 42%) rather than on a clean basis (amplitude 62%). The mean advantage to the high fleece weight line in both hogget GFW and CFW was 19%, indicating a

TABLE 2 Live weight, back fat thickness, wool production and wool characteristics of control hoggets, and differences between high fleece weight and control hoggets obtained from REML models as described in Table 1.

Variable	Control	Difference (high-control)	SE	Significance
Live weight (kg)				
Birth	4.31	0.31 (7)[1]	0.08	***
Weaning (Dec)	22.3	1.3 (6)	0.29	***
March	31.2	2.0 (6)	0.52	**
June	34.3	2.2 (6)	0.66	**
September	36.6	2.8 (8)	0.77	**
Back fat thickness (mm)[2]	2.3	-0.05 (-2)	0.09	NS
Lamb fleece weight (kg)	1.03	0.14 (13)	0.02	***
Wool growth (g/d)				
Jan-Mar	10.4	1.8 (18)	0.26	***
Mar-June	7.1	1.4 (20)	0.20	***
June-Sept	5.5	1.2 (22)	0.19	***
Hogget fleece				
GFW (kg)	2.63	0.51 (19)	0.07	***
CFW (kg)	1.76	0.34 (19)	0.05	***
Yield (%)	67.3	-0.1 (0)	0.5	NS
Staple length (mm)	103	4 (4)	2	NS
Fibre diameter (μm)	32.0	1.1 (3)	0.3	***
Loose wool bulk (cm^3/g)	22.0	-0.7 (-3)	0.4	NS
Staple strength (N/ktex)	28.7	2.7 (9)	1.5	NS
Brightness (Y)	58.8	-0.1 (0)	0.2	NS
Yellowness (Y-Z)	3.69	0.17 (5)	0.07	*

[1] % difference, relative to controls
[2] Adjusted for live weight [0.090 ±0.006 (SE) mm/kg]

negligible difference in fleece yield. The high fleece weight line grew 18, 20 and 22% more clean wool in January to March, March to June and June to September, respectively. This slightly asymmetric seasonal difference lends support to McClelland *et al.* (1987), who observed a significantly lower amplitude of wool growth in the Massey fleece weight selection line than in the contemporary control line.

For GFW there was a significant year of birth x selection line interaction ($P<0.05$), the advantage to the high fleece weight line in GFW being 0.67 ± 0.10 (SE) kg (28%) and 0.35 ± 0.12 kg (12%) for the born 1985 and born 1986 hoggets, respectively.

This interaction was not significant for CFW or wool growth from March to September although the relative differences were similar to those in GFW. Estimates of realised heritability for GFW were 0.43 and 0.20 for the born 1985 and born 1986 hoggets, respectively, giving a combined estimate of 0.32. This is similar to 0.36 - 0.42 estimated by Johnson and Dobbie (1987) as the realised heritability of hogget GFW, but both are higher than the equivalent estimates (0.10 - 0.17) of Blair *et al.* (1985).

The available evidence suggests that the difference between years in the relativity of the high fleece weight and control lines in GFW is due to a change in the production figures for the control line. Relative to a second randomly selected flock grazed with the present 2 lines, fleece weights of the control line were approximately 6% lower and 6% higher for the born 1985 and born 1986 hoggets, respectively.

There were significant interactions between sex and selection line ($P<0.05$) for CFW (but not for GFW, despite similar relative figures). The advantage to the high fleece weight line in CFW was greater for ewe hoggets (0.42 ± 0.06(SE) kg (22%)) than for ram hoggets (0.27 ± 0.06 kg (16%)). This difference may be attributable to a genotype x environment interaction as the sexes were grazed separately after weaning, or to a lower heritability for ram hoggets. In this regard, Baker *et al.* (1979) reported lower heritabilities for ram than ewe hoggets for live weight and fleece weight due to higher environmental but lower genetic variances for males.

There were no significant interactions between year born and selection line or between sex and selection line for any of the wool characterisitics measured. The differences between the high fleece weight and control hoggets in wool characterisitics are predictable from *a priori* reasoning and from published genetic relationships. The significantly higher staple length and fibre diameter of the high fleece weight hoggets is consistent with other results with Romneys (Blair *et al.*, 1985; Johnson and Dobbie, 1987). However, the estimated difference of 11 ± 3 (SE) % in fibre volume accounts for only about half of the difference between the lines in fleece weight. This suggests that the lines may differ significantly in follicle population, with the high fleece weight sheep having a high follicle density and/or a larger wool bearing surface area. This is not consistent with the indirect evidence in long-woolled breeds (Elliott *et al.*, 1979; Blair *et al.*,1985; Hawker and Littlejohn, 1986) that changes in fleece weight are accounted for by changes in fibre volume and therefore that there is little genetic variation in the follicle population. Histological studies with the present lines to allow a full component analysis are therefore warranted.

The higher staple strength of the high fleece weight fleeces is probably attributable to a high fibre cross-sectional area at the point of break. The latter was not measured but the differences between the selection lines in staple strength (9%) and estimated *average* cross-sectional area (8%), agreed closely. The higher staple strength of the high fleece weight hoggets is also consistent with the positive genetic correlation between GFW and staple strength reported by Bigham *et al.* (1983b). The regression of staple strength on wool growth in June to September did not differ significantly between selection lines in slope or intercept.

The lower bulk and significantly higher yellowness of the fleeces from the high fleece weight hoggets are consistent with known genetic and phenotypic relationships between these variables and fleece weight (Bigham *et al.*, 1983a, 1985). There was little association between fibre diameter and yellowness, indicating that the high fleece weight line's greater yellowness is not simply due to a higher mean fibre diameter.

Heritability Estimates

Heritabilities were estimated by paternal half-sib analysis (using REML) both on the control line data alone and on the control and high fleece weight line data combined (after adjustment for year born, sex, birth/rearing rank, birth date and selection line). The 2 estimates were generally similar in magnitude but those for the control line alone had large standard errors (only half the sires and a third of the animals were represented) and most were non-significant. The combined estimates shown in Table 3 must be treated with some caution given the limitations associated with the estimation of heritabilities for a trait under selection. Nevertheless most estimates are in general agreement with the literature, which gives some confidence to the estimates for traits that are not commonly reported.

The heritabilitiy estimates for live weight increased with age, as reported by Baker *et al.* (1979) and McEwan *et al.*(1984). The estimate for ultrasonic back fat thickness is consistent with that of

TABLE 3 Heritability estimates and genetic and phenotypic correlations between each variable and hogget greasy fleece weight (GFW) obtained from REML models as described in Table 1.

Variable	Heritability	Genetic correlation with GFW	Realised genetic correlation with GFW	Phenotypic correlation with GFW
Hogget greasy fleece weight	0.44 (0.16)[1]	—	—	—
Hogget clean fleece weight	0.46 (0.16)	0.99 (0.13)[1]	0.73	0.96***
Lamb fleece weight	0.14 (0.10)	0.27 (0.15)	—[2]	0.48***
Wool growth Jan-Mar	0.32 (0.14)	0.88 (0.23)	0.80	0.78***
Wool growth Mar-June	0.37 (0.15)	0.83 (0.21)	0.77	0.87***
Wool growth June-Sept	0.37 (0.15)	0.94 (0.23)	0.67	0.87***
Fleece yield	0.51 (0.17)	-0.18 (0.11)	-0.02	-0.02 NS
Mean fibre diameter	0.33 (0.13)	0.37 (0.14)	0.48	0.54***
Staple length	0.34 (0.14)	0.88 (0.24)	0.20	0.39***
Staple strength	0.52 (0.17)	0.79 (0.20)	0.18	0.39***
Loose wool bulk	0.46 (0.16)	-0.44 (0.15)	0.18	-0.09*
Brightness	0.23 (0.12)	0.50 (0.21)	-0.08	0.05 NS
Yellowness	0.04 (0.07)	0.64 (0.74)	0.65	0.16***
Birth weight	0.11 (0.09)	—	—	0.30 **
Weaning weight	0.03 (0.08)	—	—	0.43***
Live weight (6 months)	0.20 (0.11)	—	0.51	0.59***
Live weight (9 months)	0.40 (0.15)	0.73 (0.19)	0.33	0.70***
Hogget live weight	0.47 (0.16)	0.69 (0.17)	0.34	0.71***
Back fat thickness	0.25 (0.12)	-0.37 (0.17)	-0.06	-0.07 NS

[1] Standard error of the estimate
[2] Estimate unreliable due to low heritability

McEwan *et al.* (1984). The low heritability of lamb fleece weight and moderate to high estimates of heritability for wool production and most wool characteristics except colour are consistent with published estimates for Romneys and other long-woolled breeds (Baker *et al.*, 1979; Bigham *et al.*, 1983a, b, 1985). The present data and those of Bigham *et al.* (1983a) suggest that only slow progress would accompany selection for improvement in either brightness or yellowness.

Genetic and Phenotype Correlations

Table 3 also shows realised genetic correlations with GFW, corresponding genetic correlations estimated from the paternal half-sib analysis and phenotypic correlations with GFW estimated after adjusting the data for environmental effects. These phenotypic correlations and others estimated between wool production and wool characteristics are in general agreement with published figures.

Both sets of genetic correlations are consistent in sign with the differences between the selection lines (Table 2). However, the realised estimates are generally considerably lower than the half-sib estimates. The positive genetic correlations between GFW and live weight agree with the results of Baker *et al.* (1979). The present results support other findings (Elliott *et al.*, 1979; Bigham *et al.*, 1983a, b; Blair *et al.*, 1985) by clearly indicating that selection for GFW is accompanied by increases in fibre volume, staple strength and yellowness and a reduction in loose wool bulk. However, correlated changes in other components of fleece weight are not precluded by these estimates.

Tests for Segregation

Of the sires used in 1985 the single gene test was significant for 1 sire for both hogget GFW and hogget live weight ($P<0.001$ in both cases) and for a second sire for GFW ($P<0.005$). The putative single genes had estimated effects of approximately 1 kg for GFW and 12 kg for live weight. From the sires identified and their progeny 2 rams most likely to be carrying a single gene for GFW were extensively progeny tested at the 1987 joining. The resulting data should be adequate to confirm (or dismiss) the existence of a single gene effect. The segregation test was not significant for any of the sires used in 1986.

CONCLUSION

These results show that large scale screening of high fleece weight ewes and rams is an effective way to initiate a high fleece weight selection line. The progeny's advantage in fleece weight is equivalent to 2 to 3 generations of genetic progress in a selection line established from a random base population (Morris, 1980). That exceptional genotypes, such as major single genes, may be isolated is an important feature of the screening exercise. With the exception of slightly poorer colour the high fleece weight hoggets had superior wool characterisitcs. This supports the contention that the direct and correlated benefits accruing from selection for high fleece weight make it an attractive selection objective for long-woolled breeds.

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