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GENETIC PARAMETERS OF LIFETIME WOOL PRODUCTION

J.N. CLARKE, J.L. DOBBIE, S.M. HICKEY, K.R. JONES AND A.L. WRIGGLESWORTH

AgResearch, Ruakura Research Centre, Hamilton, New Zealand.

ABSTRACT

Heritabilites and genetic correlations were estimated from the selected and control lines of a 25-year selection experiment for hogget greasy fleece weight (GFW). The heritability of GFW was higher in the selected than the control line and in female hoggets (0.48) compared with males (0.32). Inter-age genetic correlations were less than unity, and higher in fleece weight selected animals. Average genetic correlations between hogget and adult records were higher in ewe than ram hoggets. Together these parameters gave co-heritability estimates (pooled across lines) for greasy hogget with clean adult ewe fleece weights of nearly half the average magnitude in males (0.21) compared with females (0.36). These results have important repercussions to the design of effective selection strategies for improvement of lifetime wool production.

Keywords: genetic parameters; male and female hoggets; selection; lifetime wool production.

INTRODUCTION

Most improvement schemes for crossbred sheep rely on greasy hogget fleece weight as the selection criterion and have the implicit aim of improving returns to producers through enhanced lifetime clean wool production. However, most breeding schemes have been designed on the assumptions that:

- the genetic correlation of greasy with clean wool production is close to unity at all ages, i.e. reflect the same genetic characteristic of each age
- relevant phenotypic and genetic parameters among indicator and goal traits are the same in both sexes.

Under these assumptions hogget greasy fleece weight can be thought of as the improvement goal as well as the selection criterion.

This study seeks to examine these assumptions, as part of an analysis of genetic responses to selection for greasy hogget fleece weight, with the ultimate aim of examining alternative selection strategies for the improvement of lifetime clean wool production in Romney sheep.

MATERIAL AND METHODS

The data come from a selection experiment established at Whatawhata by the late Graeme Hight (Johnson *et al.* 1995a). Selection was on hogget greasy fleece weight among animals born in 1969 to 1990. Animals were shorn as lambs in December, as hoggets in August (males) or October (females) and as breeding ewes in December. Responses were examined for lamb greasy fleece weight, for clean fleece weight as ewe and ram hoggets and, in a sub-sample of animals, for 2-5 year-old (yo) ewe greasy and clean fleece weights (Johnson *et al.* 1995b).

In this paper, attention has focused on within-line estimates of genetic parameters for greasy and clean fleece weight expressions at different ages. No correction for environmental effects other than those associated with year of birth was undertaken.

A restricted maximum likelihood (REML) animal model was fitted which included fixed effects associated with year of birth, and selection line. Although sampled from the same base population, pedigree links were not available to common base parents. Parameters were also estimated separately by sex in each of the fleece weight selected (FW) and unselected control (CO) lines. The average information method (AIREML program) of Johnson and Thompson (1994) was used.

Not all shorn lambs were available for measurement as hoggets and not all hoggets were chosen for entry into the breeding flock, those in the FW line having been selected on their hogget record. For this reason parameters were estimated using three- or four-trait multivariate models which, to account for the selection, included the earlier lamb and hogget records.

RESULTS

Information Available

The number of fleece weight records by line and age at shearing are presented in Table 1.

TABLE 1: Number of records analysed for each trait and the distribution of ewe clean fleece weight records across years.

		Age at shearing					
		lambs	hoggets	2-yo	3-yo	4-yo	5-yo
Males	Greasy	2715	1661				
	Clean	-	1265				
Females	Greasy	2969	2618	2043	1684	1335	1048
	Clean		2178	591	486	437	346
Year born	1977		122				57
	1978		116			85	
	1979				61		47
	1980			80		48	40
	1981						
	1982		109	94	81	67	43
	1983			90	76	53	28
	1984		95	77	56	38	37
	1985		117	61	43	36	28
	1986		113	47	52	45	34
	1987		85	72	61	45	32
	1988		107	70	56	50	
	1990		67				

On average 61% of ram hoggets and 88% of ewe hoggets that were shorn as lambs were shorn and had their greasy fleeces weighed (GFW) as yearlings. Of the ewe hoggets shorn, 78 % had GFW records as 2-yo, 64% as 3-yo, 51% as 4-yo and 40% as 5-yo.

Because of the costs involved, fewer animals were assessed in terms of clean fleece weight (CFW) as hoggets - 76% of ram hoggets, 83% of ewe hoggets, but on average only 31% of older ewes had CFW records. Of these mature CFW records, 80% were taken over a 7-year period towards the end of the experiment (1982-1988 birth years).

Greasy Fleece Weight

Phenotypic and genetic parameters, pooled within each of the two selection lines, are presented in Table 2.

The heritability of GFW declined progressively from yearling (0.48) to 5-yo ewes (0.30), differences of the order of 0.07 being significant (P<0.05) assuming a normal distribution of estimates. A similar trend for paternal half-sib estimates in Perendales was reported by Lewer *et al.* 1983a. The estimate was higher in ewes compared with rams as both hoggets and lambs, and in hoggets compared with lambs for both sexes. The repeatability of GFW (average inter-age phenotypic correlation for ewe hoggets and older ewes), was 0.58 (38% higher than the average heritability of 0.42).

Genetic correlations among adult records were on average 0.30 higher than the corresponding phenotypic correlations. Correlations among 2-yo to 5-yo records were more similar than those involving ewe hogget records, especially at the phenotypic level. As shown in the last row of the lower triangular matrices in Table 2, each of the adult records had a similar average genetic correlation with GFW expressions as one to five year-olds (0.93), indicating a similar accuracy of predicting lifetime greasy wool production from a single record. The corresponding hogget correlations were lower: 0.86 (i.e. by 8%) for ewe hoggets , 0.80 (by 14%) for ram hoggets and 0.60 (by 35%) for both ewe and ram lambs

Clean Fleece Weight

Phenotypic and genetic parameters are presented in Table 3.

The average heritability of CFW in females was 0.45, similar to the pooled value of 0.48 shown in Table 3. It was higher (P<0.05, assuming normality) for FW (0.50) than for CO (0.40) hoggets, almost as high as the repeatability estimate (average inter-age phenotypic correlation) which was 0.45 for CO animals and 0.52 for animals in the FW line. Apart from this exception, the repeatability of CFW among adult ewes was on average 25% higher than the corresponding average heritability.

Inter-age genetic correlations averaged 0.86, significantly different from unity (P<0.05, assuming normality), and similar for both lines. Among adults these correlations were on average higher in FW (0.91) than in CO (0.83) animals.

DISCUSSION

Averaged across sexes, the heritability estimate for hogget GFW was very close to the estimate of 0.39 obtained for this flock by Johnson *et al.* (1995a,b) who fitted an animal model with fixed effects associated with age of dam, birth/rearing rank and birth day in addition to year x sex and line effects. Thus our exclusion of environmental effects associated with age of dam, birth/rearing rank and birth day, had no impact on the estimate obtained for this trait.

A univariate animal model fitting an additional random term representing a maternal genetic effect and a direct-maternal genetic covariance gave a more similar average

TABLE 2: Pooled parameter estimates for greasy fleece weight fitting animal + line + year born

									Standard Errors							
	mGl	mGh	fGl	fGh	fG2	fG3	fG4	fG5	mGl	mGh	fGl	fGh	fG2	fG3	fG4	fG5
Genetic																
mGl	**.09**								.03							
mGh	.63	**.32**							.25	.04						
fGl	**1.00**	.47	**.24**						.27	.16	.04					
fGh	.74	**.98**	.58	**.48**					.21	.13	.10	.03				
fG2	.65	.75	.59	.86	**.45**				.24	.14	.10	.06	.03			
fG3	.59	.82	.61	.87	.92	**.44**			.24	.16	.10	.07	.06	.03		
fG4	.42	.68	.58	.75	.89	.96	**.42**		.21	.16	.11	.07	.07	.08	.03	
fG5	.53	.76	.63	.82	.92	.97	.99	**.30**	.24	.17	.14	.08	.10	.10	.08	.03
Ave rg	.59	.80	.60	.86	.92	.94	.92	.94								
Phenotypic																
mGl	**.250**								.003							
mGh	.41	**.586**							.033	.018						
fGl	n/a	n/a	**.233**						n/a	n/a	.003					
fGh	n/a	n/a	.44	**.511**					n/a	n/a	.03	.010				
fG2	n/a	n/a	.27	.55	**.505**				n/a	n/a	.03	.02	.016			
fG3	n/a	n/a	.31	.52	.64	**.602**			n/a	n/a	.03	.03	.02	.018		
fG4	n/a	n/a	.28	.48	.57	.68	**.634**		n/a	n/a	.03	.03	.03	.03	.020	
fG5	n/a	n/a	.24	.43	.60	.64	.67	**.635**	n/a	n/a	.031	.03	.03	.03	.02	.020
Ave rp	n/a	n/a	.31	.60	.67	.70	.68	.67								

(symbols: m/f = male/female; G/C = greasy/clean; l/h/2...5 = lamb/hogget/2...5 yo records; n/a = not applicable) heritability estimate across sexes for GFW. These additional terms were important only in the case of male hoggets. A random litter effect was also investigated and had no impact in either sex. Mortimer and Atkins (1994) have reported that inclusion of a maternal genetic effect was important for yearling Merino ewes and served to make the direct heritability estimates more similar to those obtained from a sire model.

The present analyses chose (initially) to use a simple animal model without additional random terms in order to more easily accommodate the multivariate approach needed to estimate correlations among different traits (measurements in different sexes and at different ages) in records subject to the effects of selection.

The heritability estimate of GFW in male hoggets was lower than that in female hoggets (0.32 vs 0.48), the average value (0.4) being higher than that currently used by Animalplan (0.35). Although no adjustment was made for reproductive status, the average heritability estimate for GFW adult records (hoggets to 5-yo) was 0.42, also towards the high end of the range of published estimates (most of which are based on ram and ewe hogget records), but similar to the estimates for adult Perendale ewes obtained by Lewer *et al.* (1983a).

There was some evidence, supported by the corresponding repeatabilities, of an increase in the heritability of hogget fleece weight in females as a result of selection. Average inter-age genetic correlations were also higher in the FW line. Apart from these exceptions, the results did not reveal any major significant line differences in parameter estimates for CFW, but the experiment was not well designed for this purpose (inadequate subsample size and age/year distribution of CFW records), as reflected in the standard errors.

Of particular note from the more definitive GFW estimates (Table 2) is the size of the average genetic correlation between hogget and adult (2-5 yo) records, being 0.86 for ewes and 0.80 for rams. The corresponding average genetic correlations of hogget GFW with hogget and adult CFW were even lower, 0.78 and 0.55 respectively.

Table 4 presents a summary of important average values relevant to the prediction of lifetime clean wool production (measured as the unweighted average of hogget to 5-yo records), from lamb and hogget greasy fleece weights. The important covariances between GFW in rams and CFW in ewes, are presented in the final column of the table as the standardised genetic covariance or co-heritability, estimated as the product of the square root of the two heritabilites with the genetic correlation between them. It is the indirect selection analogy with the heritability parameter under direct selection, representing the fraction of the selection differential in the selection criterion that is passed on as improvement in the breeding objective (in this case average lifetime clean wool production).

The co-heritabilities indicate that selection of male hoggets, while capable of higher selection differentials, is much less accurate (approx. 60%) than selection among female hoggets. Indeed the level of accuracy is more similar to that for selection among females as lambs.

There is little published information on co-heritabilities involving these traits. For Merinos, Atkins *et al.* (1990) present a corresponding co-heritability of 0.23 for 15-month GFW in rams (12 months wool growth) and adult CFW, a value which is similar to the ram hoggets in this study.

TABLE 3: Pooled parameter estimates and standard errors for clean fleece weight

										C	Standard Errors						C	C	C	C
	mGl	mGh	fGl	fGh	mCh	fCh	fC2	fC3	fC4	fG5	mGl	mGh	fGl	fGh	mCh	fCh	fG2	fG3	fG4	fG5
Genetic																				
mGl	**.10**										.03									
mGh	.65	**.32**									.15	.05								
fGl	.99	.47	**.23**								.02	.08	.04							
fGh	.62	1.00	.56	**.47**							.12	.16	.07	.04						
mCh	.54	.96	.36	.96	**.29**						.16	.01	.12	.01	.06					
fCh	.45	.85	.51	.97	.97	**.48**					.10	.05	.07	.03	.13	.04				
fC2	.23	.45	.42	.73	.62	.88	**.53**				.24	.18	.14	.11	.14	.07	.06			
fC3	.31	.51	.49	.79	.72	.94	.90	**.48**			.27	.20	.16	.11	.18	.08	.13	.06		
fC4	.16	.50	.47	.61	.70	.71	.82	.88	**.50**		.24	.18	.17	.13	.17	.10	.16	.18	.08	
fC5	.47	.47	.47	.81	.65	.98	.92	1.00	1.00	**.31**	.48	.30	.21	.18	.24	.18	.21	.24	.27	.08
Ave rg	.32	.56	.47	.78	.73	.90	.90	.94	.88	.98										
Phenotypic																				
mGl	**.250**										.003									
mGh	.41	**.586**									.02	.011								
fGl	n/a	n/a	**.233**								n/a	n/a	.007							
fGh	n/a	n/a	.44	**.510**							n/a	n/a	.02	.008						
mCh	.38	.95	n/a	n/a	**.474**						.02	.01	n/a	n/a	.009					
fCh	n/a	n/a	.41	.94	n/a	**.443**					n/a	n/a	.02	.01	n/a	.007				
fC2	n/a	n/a	.24	.50	n/a	.55	**.454**				n/a	n/a	.04	.04	n/a	.03	.016			
fC3	n/a	n/a	.24	.47	n/a	.53	.61	**.577**			n/a	n/a	.04	.04	n/a	.04	.04	.021		
fC4	n/a	n/a	.22	.40	n/a	.44	.53	.62	**.551**		n/a	n/a	.06	.06	n/a	.04	.06	.06	.026	
fC5	n/a	n/a	.20	.36	n/a	.40	.54	.62	.61	**.548**	n/a	n/a	.06	.06	n/a	.06	.06	.06	.07	.027
Ave rp	n/a	n/a	.26	.53	n/a	.58	.65	.68	.64	.63										

(symbols: m/f = male/female; G/C = greasy/clean; l/h/2...5 = lamb/hogget/2...5 yo records; n/a = not applicable)

TABLE 4: Prediction of lifetime clean wool production.

Indicators		Genetic Correlations				Coh^2
Trait	h^2_{GFW}	mCh	fCh	E_{2-5}	L_{h-5}	[relative values]
mGl	**.10**	.54	.45	.29	.32	.07 [19]
mGh	**.32**	.96	.85	.48	.56	.21 [59]
fGl	**.23**	.36	.51	.46	.47	.15 [42]
fGh	**.47**	.96	.97	.74	.78	.36 [100]
Average	h^2_{CFW}	**.29**	**.48**	**.46**	**.46**	

(symbols: m/f = male/female; GFW/CFW = greasy/clean fleece weight; l/h = lamb/hogget; E_{2-5} = average for 2-5 yo ewes; L_{h-5} = average for 1-5 yo females).

Of particular impact on these co-heritabilities is the extent to which the genetic correlation is significantly different from unity. Lewer *et al.* (1983b) reported a genetic correlation of 0.53 between yearling and lifetime average GFW, albeit with a high standard error (0.23). Atkins (1990) reports genetic correlations of yearling CFW in ewe hoggets and CFW of 2 to 6 year-old ewes which average 0.77, lower than the average value of 0.90 presented in Table 3 but close to the average value of 0.78 for ewe hogget GFW (Table 4). Our corresponding average values for ram hoggets were 0.73 and 0.56. The review of Atkins (1990) also points to other evidence of genetic correlations of 0.8 or less, even for young ewes.

These results have important repercussions to the design of effective improvement programmes for wool production. For example, paternal half sib information on females, as both hoggets and lambs and perhaps even at older ages, is likely to be more important than has been previously recognised.

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