Proc. Assoc. Advmt. Anim. Breed. Genet. ***17****: 103-106*

IS INCREASED FLEECE WEIGHT ASSOCIATED WITH REDUCED REPRODUCTION RATE? RESULTS FROM LONG TERM MULTI-TRAIT SELECTION FLOCKS

L.R. Piper[1], A.A. Swan[2] and H.G. Brewer[1]

[1]CSIRO Livestock Industries, F D McMaster Laboratory, Armidale, NSW 2350. [2]Animal Genetics and Breeding Unit, University of New England, Armidale, NSW 2351

SUMMARY
Medium-Peppin Merino sheep were selected for increased fleece weight with independent culling for various fleece quality traits over the period 1947 to 1966 at the CSIRO, National Field Station, Cunnamulla, Qld. There were two lines selected in different ways for increased fleece weight and a random bred control flock was initiated in 1950. Data from these flocks have been analysed to estimate genetic responses in fleece weight and in reproduction rate. For animals born over the period 1950 to 1964: (i) fleece weight increased in both selection lines with an average response in 18 month clean fleece weight of around 2 % per year (ii) there was no change in fleece weight in the control line (iii) there was no change in reproduction rate (lambs weaned/ewe joined for all lambing opportunities between 3 and 7 years of age) in any of the lines. These results demonstrate that long term breeding programs for Merino sheep, which include increased fleece weight as a component of a multi-trait breeding objective, can be implemented without necessarily reducing reproduction rate.

INTRODUCTION
In a recent series of papers (eg Adams *et al.* 2006), arguments and data have been presented suggesting that “high clean fleece weight (CFW) sheep have smaller metabolic reserves to withstand unfavourable feed conditions and so may be less able to thrive and reproduce successfully in harsh feed environments”. Associated popular press articles have noted that (i) “these (high CFW) sheep can have difficulty maintaining body reserves without a plentiful food supply and as a result can produce fewer lambs” and (ii) “simply put, the findings show that if we push too much for production we can muck up the sheep’s chance of reproducing” (http://www.csiro.au/news/ps1y5.html).

At the CSIRO National Field Station, Gilruth Plains, Cunnamulla, Qld., medium-Peppin Merino sheep were selected for increased fleece weight with independent culling for various fleece quality traits over the period 1947 to 1966. There were two lines selected in different ways for increased fleece weight and a random bred control flock was initiated in 1950. The environment and management of the sheep has been described by Turner *et al.* (1959). Gilruth Plains is located in a summer rainfall semi-arid region with average annual precipitation of about 375 mm. There is considerable annual variation in rainfall and this unreliability is the main factor challenging animal production from pasture. During the period from 1947 to 1966, there were droughts in 1958, 1960 and 1965 that were sufficiently severe to preclude mating of the experimental flocks.

In this paper, we have analysed data from these flocks to estimate genetic responses in fleece weight and in reproduction rate (NLW/EJ). It is known from earlier studies (Turner *et al.* 1968) that for animals born over the period 1947 to 1964, the annual rates of increase in CFW were around 2% in both selection lines. It is therefore of interest to ask whether, in this relatively harsh semi-arid environment, the genetic change in CFW from selection on a multi-trait breeding objective to improve production over that period was accompanied by a correlated change in reproduction rate.

MATERIALS AND METHODS

Sheep and Selection Lines. The foundation ewes for the selection lines were typical medium-wool Merino ewes of mixed Peppin origin. Rams were purchased in 1947 from a Peppin stud in central Queensland (Turner *et al.* 1968). In 1947 ewes were allocated at random (within age groups for ewes but not for rams) to each of two selection lines (S and MS). Subsequent measurements on surviving base ewes and rams showed that the ewes allotted to the two selection lines were similar in measured characters (fleece weight, fibre diameter, etc.) but the rams exhibited differences which persisted in their descendents (Turner *et al.* 1968). A random bred control flock (C) was established in 1950.

In the data analysed for this paper, the selection history for the S and MS lines can be divided into two periods. In the first (1950 to 1959), both lines were selected for increased CFW with concurrent selection against high fibre diameter (FD) and high degree of skin wrinkle (Wr, scored 1, plain, to 10). In the S line, the performance of the ram's half-sibs were considered as well as his own performance for the selection traits. In the MS line, mass selection only was practised. In the second period (1961 -1964), mass selection was used for both sexes in both lines, with selection against high FD and Wr in S and against low crimp frequency (Cr) and high Wr in MS. Full pedigrees were obtained for all animals in each line from the 1951 drop onwards (Turner, *et al.* 1968).

Table 1. Numbers of animals by selection line and observations for each trait, trait means and standard deviations

Trait	Number of animals by line			Number of observations	Mean	SD
	S	MS	C			
NLW/EJ	561	452	525	4597	0.89	0.44
CFW (kg)	1247	917	1023	3187	2.3	0.6
FD (micron)	1259	922	1034	3215	21.7	2.1
Cr (crimps/in)	1259	922	1034	3215	27.3	11.8
Wr (visual score)	1260	926	1034	3220	3.7	1.4

Observations and data analysis. Ten wool and body characteristics were measured on all animals using the techniques described by Turner *et al.* (1953). For the purpose of these analyses, the data consisted of measurements of CFW, FD, Wr and Cr taken from 18 month ewes (previously shorn at 6 months) and the reproduction records (NLW/EJ) of the same ewes at their 3 to 7 year old lambings inclusive, as summarised in Table 1. All of the wool and body measurements and most of the reproduction records were obtained at Gilruth Plains. The flock was transferred to the CSIRO Field Station, Longford, Armidale, NSW in 1966 and some of the later reproduction records for the 1961 to 1964 drop ewes were obtained at Longford.

The data were analysed using the software package WOMBAT (Meyer 2006). In order to account for the effects of selection, NLW/EJ was fitted simultaneously with CFW, FD, Wr and Cr in a five trait multivariate analysis to estimate genetic parameters. The model for the analysis of the data was:

$$y = X\beta + Z_u u + Z_m m + Z_p pe + e$$

where y is a vector of observations on all traits, X, Z_u Z_m, and Z_p are incidence matrices linking observations to fixed effects (β), direct breeding values for all traits (u), maternal breeding values for

CFW (*m*), and permanent environment effects for NLW/EJ (*pe*). The vector *e* denotes residual effects for each trait. Variance structures for random effects are:

$$Var(u) = G \otimes A \qquad Var(m) = \sigma_m^2 A \qquad Var(pe) = \sigma_{pe}^2 I \qquad Var(e) = R \otimes I$$

where *G* is the genetic covariance matrix for the five traits in the analysis, *A* is the numerator relationship matrix of all animals in the pedigree and the symbol $\otimes$ denotes the matrix direct product operation. *R* is the residual covariance matrix and *I* denotes identity matrices of appropriate order.

Fixed effects fitted included management group, birth type and rearing type for all traits and ewe age in years for NLW/EJ. The data were adjusted by fitting covariates for % inbreeding (all traits), shearing age (CFW) and age of dam (linear and quadratic) for CFW, FD, Wr and Cr. Genetic trends for NLW/EJ and CFW were calculated by averaging estimated breeding values (*u*) by year of birth.

RESULTS AND DISCUSSION

Estimates of genetic and phenotypic parameters for the five traits included in this analysis are presented in Table 2. The estimates generally accord with expectation but those for the heritability of CFW and for the genetic correlation between CFW and NLW/EJ are at the high end of the range of published estimates (Safari *et al.* 2005).

Table 2. Parameter estimates (± standard errors) with phenotypic variances (first row), heritabilities (in bold), genetic correlations below diagonal and phenotypic correlations above diagonal (in italics)

	NLW/EJ	CFW	FD	Cr	Wr
Phen var.	0.09 ± 0.00	0.11 ± 0.00	3.06 ± 0.09	25.99 ± 0.81	1.12 ± 0.03
NLW/EJ	**0.03 ± 0.01**	*-0.02 ± 0.02*	*0.00 ± 0.02*	*-0.01 ± 0.02*	*-0.04 ± 0.02*
CFW	-0.42 ± 0.16	**0.49 ± 0.04**	*0.15 ± 0.02*	*-0.38 ± 0.02*	*0.11 ± 0.02*
FD	-0.09 ± 0.16	0.22 ± 0.07	**0.54 ± 0.04**	*-0.15 ± 0.02*	*0.10 ± 0.02*
Cr	0.05 ± 0.15	-0.58 ± 0.05	-0.23 ± 0.06	**0.58 ± 0.04**	*0.14 ± 0.02*
Wr	-0.24 ± 0.16	0.09 ± 0.07	0.11 ± 0.07	0.24 ± 0.07	**0.45 ± 0.04**

The estimated genetic trends for CFW and NLW/EJ are shown in Figure 1. For animals born over the period 1950 to 1964: (i) fleece weight increased in both S and MS lines with an average response in 18 month CFW of around 2 % per year (ii) there was no change in CFW in the C line (iii) there was no change in NLW/EJ (for all lambing opportunities between 3 and 7 years of age) in any of the lines.

Given the sign and magnitude of the estimated genetic correlation between CFW and NLW/EJ in these data, it is perhaps surprising that the increase in CFW was not accompanied by a decrease in NLW/EJ. We have therefore used the estimated parameters derived from these data to predict the outcome of the multi-trait selection employed in the S line. The traits in the breeding objective were CFW and FD (maximise the increase CFW and maintain FD), Wr (restricted to zero genetic change). Genetic changes in NLW/EJ were monitored by applying a zero economic weight to the trait. Selection criteria included CFW, FD and Wr. For selection intensities and generation intervals applicable to the S line, CFW and NLW/EJ were predicted to show annual genetic changes of 2.6%

and -0.6% respectively. The observed response in CFW was slightly less than predicted but there was no change in NLW/EJ. The estimated genetic correlation between CFW and NLW/EJ (-0.42) is outside the 95% bounds for this correlation in the review of Safari *et al.* (2005). However, the standard error on our estimate is high (0.16) and the realised correlation of zero is much closer to the weighted mean correlation (-0.12) for these traits in Safari *et al*. (2005).

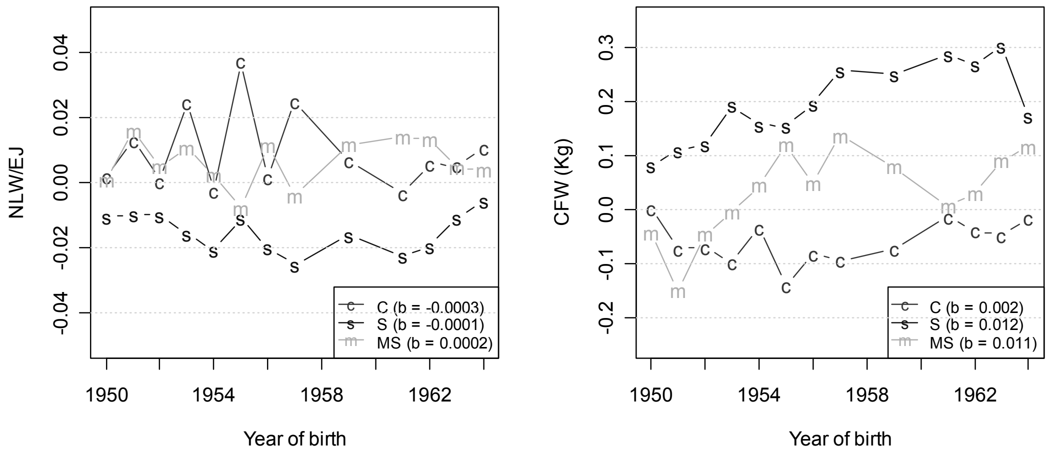

Figure 1. Genetic trends for NLW/EJ and CFW in each selection line. Linear regression coefficients for each line (b) shown in the legends.

CONCLUSIONS

The breeding programs reviewed in this paper aimed to increase CFW while maintaining FD and degree of body wrinkle. There was no attempt to increase or maintain body weight or NLW/EJ. Over the 19 years of the experiment, conducted in a relatively harsh western Queensland environment, the substantial increase in CFW was not accompanied by any change in NLW/EJ. These results accord with current predictions of breeding program outcomes from a wide range of multi-trait breeding objectives for sheep (eg http://www.sheepgenetics.org.au/merinoselect/reports/MERINOSELELECT Indexes 20060523.pdf).

REFERENCES

Adams, N.R., Briegel, J.R., Greeff, J.C. and Bermingham, E.N. (2006) *Aust. J. agric. Res.* **57**, 27.
Meyer, K (2006) WOMBAT – a program for mixed model analyses by restricted maximum likelihood. User notes. Animal Genetics and Breeding Unit, Armidale, 55pp.
Turner , H.N., Dolling, C.H.S. and Kennedy, J.F. (1968) *Aust. J. agric. Res.* **19**, 79.
Turner, H.N., Dolling, C.H.S. and Sheaffe, P.H.G. (1959) *Aust. J. agric. Res.* **16**, 699.
Turner, H.N., Riches, J.H., Hayman, R.H., Roberts, N.F. and Wilson, L.T. (1953) Physical definition of sheep and their fleece, with special reference to the Merino. CSIRO Div. Anim. Health, Div Rept. No. 4, Ser. SW-4.
Safari, E., Fogarty, N.M. and Gilmour, A.R. (2005) *Livest. Prod. Sci.* **92**, 271.