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Genetic studies on the South African Mutton Merino: growth traits

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Abstract

Genetic parameters were estimated for 36-, 42-, 50-, 100- and 150-day weight in the South African Mutton Merino breed. The direct heritability estimates obtained were 0.270, 0.366, 0.278, 0.185 and 0.115 respectively. The maternal heritability estimates for the respective weights were 0.494, 0.249, 0.129, 0.091 and 0.080. The correlation between the animal effects (direct and maternal) varied between –1.000 for 36-day weight to –0.376 for 150-day weight. Very little selection progress was made over the period (1980-1999) in the breed.

Keywords: Genetic parameters, genetic trends, maternal ability, SA Mutton Merino Sheep
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Introduction

The South African Mutton Merino is a dual-purpose (mutton and wool) sheep breed that was developed by selection from the imported German Merino. The distinct possibility of a rapid increase in the export volume of genetic material has stressed the need for more widespread accurate genetic evaluations. The first step in this process will be the construction of an operational model and the estimation of relevant genetic parameters. Although the South African Mutton Merino was, strictly speaking, not initially developed in South Africa, the breed has undergone such a metamorphosis that it no longer bears much, if any, resemblance to its European ancestor. The need for a separate genetic characterization of this distinct South African strain is therefore evident. The aim of this study was to determine the applicable non-genetic factors and to estimate genetic parameters for several growth traits within the constraints of the field data available for the breed.

Material and Methods

A total of 387 600 pedigree and 126 477 performance records were available from the South African Mutton Merino Breed Society. These records spanned a period of 25 years, from 1974 to 1999, and were obtained from 254 studs situated throughout South Africa. All studs are genetically linked, since AI is used extensively in the breed and many sires change hands annually. Animals were weighed only once in their lifetime and therefore have only a 50-day, 100-day or 150-day weight. The data-set containing 50-day weights was divided into two subsets, i.e. 36- and 42-day weight, with some overlap between the weights. This was done to determine the pattern of the covariance between the animal effects over time. After editing the following records were available (Table 1):

Table 1 Description of data

	36-day weight	42-day weight	50-day weight	100-day weight	150-day weight
Number of animals	2002	6117	10254	63662	6269
Number of sires	193	292	373	1608	316
Number of studs	14	14	17	91	27
Number of dams	1269	2857	4107	25053	3627
Average progeny per sire	10.40	20.95	19.84	39.59	27.50
Average progeny per dam	1.58	2.14	2.50	2.54	1.72
Average contemporary group size	25.03	53.19	46.10	69.38	73.21
Average weight (kg)	16.27	17.48	19.48	30.64	35.54
Standard deviation (kg)	4.62	5.15	5.91	7.40	8.59
Coefficient of variation (%)	28.40	29.46	30.34	24.15	24.17
Average age (days)	36.76	43.88	51.05	102.30	145.68
Standard deviation (days)	5.35	7.05	11.00	13.44	11.52
Period	1986-1999	1986-1999	1986-1999	1980-1999	1991-1999

The 42-day weight of the lamb is generally regarded as being indicative of the milk production and nursing ability of its dam, while the 100-day weight represents the weaning weight of the lamb. The post-weaning growth of the lamb is reflected in the 150-day weight of the animal.

In order to identify the effects to be included in the fixed part of the model, an analysis of variance was performed on a concatenation of flock, birth year and season of birth (FYS), sex, birth status, age of dam and age at the time of weighing. All the effects included were highly significant ($P \leq 0.01$) for all traits and hence included in the model. The DFREML program of Meyer (2000) was used to estimate genetic parameters for the five traits. Tests of significance of the covariance between direct and maternal effects were performed by testing the improvement in the log likelihood by either excluding or including the covariance. Although this test was performed on all the traits, it was decided to only present the results of the test performed on the 100-day weights, as this data set had the most records. The following five linear models were tested:

$y = X\beta + Z_1a + e$ Model 1
$y = X\beta + Z_1a + Z_2m + e$ Model 3 (Maternal effect not correlated with direct effect)
$y = X\beta + Z_1a + Z_2m + e$ Model 4
$y = X\beta + Z_1a + Z_2m + Z_3c_1 + e$ Model 8.1
$y = X\beta + Z_1a + Z_2m + Z_3c_1 + Z_4c_2 + e$ Model 8.2

where **y** is a **nx1** vector of records, **X** is a **nxp** incidence matrix that relates data to the unknown vector of location parameters **ß.** The vector **ß** contained flock-year-season, sex, birth status and age of dam as fixed effects while age at weaning were included as a linear and quadratic regression. The incidence matrices $\mathbf{Z_1}$ and $\mathbf{Z_2}$ relate the unknown random vectors of direct breeding value (**a**) and maternal breeding value (**m**), respectively, to **y**. The incidence matrices $\mathbf{Z_3}$ and $\mathbf{Z_4}$ relates the unknown additional random vectors, permanent maternal environment ($\mathbf{c_1}$) and flock-year-season x sire interaction ($\mathbf{c_2}$), also to **y**. The unknown vector **e** contains the random residuals due to environmental effects peculiar to individual records. After testing the five models it was decided to fit the following model for all the traits:

$y = X\beta + Z_1a + Z_2m + Z_3c_1 + e$ Model 8.1

Results and discussion

The (co)variance components and heritability estimates obtained for 100-day weight using the five different models are presented in Table 2.

Table 2 (Co)variance components and heritability estimates obtained for 100-day weight using the five different models

	Model 1	Model 3	Model 4	Model 8.1	Model 8.2
Direct heritability	0.337	0.138	0.184	0.185	0.026
Maternal heritability	-	0.126	0.203	0.091	0.060
Covariance as proportion of total variance	-	-	-0.092	-0.071	0.001
Permanent maternal environment	-	-	-	0.100	0.094
Flock-Year-Season x Sire interaction	-	-	-	-	0.067
Direct additive variance	8.451	3.354	4.494	4.496	0.644
Maternal additive variance	-	3.057	4.966	2.216	1.460
Variance due to permanent maternal environment	-	-	-	2.418	2.306
Variance due to Flock-Year-Season x Sire interaction	-	-	-	-	1.630
Covariance between animal effects	-	-	-2.258	-1.727	0.018
Error variance	16.65	17.862	17.221	16.912	18.430
Phenotypic variance	25.102	24.275	24.422	24.315	24.488
Correlation between animal effects	-		-0.478	-0.547	0.018
Log likelihood[1]	575.14	22376.62	22353.68	223.38	0.00

[1] As deviation from the most suitable model

Although the log likelihoods indicate that Model 8.2 is the most appropriate one to use, it is not practical. The inclusion of the flock-year-season x sire interaction lead to a substantial decrease in both the direct heritability and the correlation between the animal effects. Direct heritability decreased to almost zero A decrease in maternal heritability also occurred. This is in agreement with results obtained by Neser *et al.* (1998), also with Mutton Merinos. Sires are largely nested within flock-year-seasons and this makes the analysis inappropriate. It was therefore decided to use Model 8.1 in the analysis of all the traits. The (co)variance components and heritability estimates obtained for the five traits are presented in Table 3.

Table 3 (Co)variance components and heritability estimates for the five traits

	36-day weight	42-day weight	50-day weight	100-day weight	150-day weight
Direct heritability	0.270	0.366	0.278	0.185	0.115
s.e.	0.120	0.060	0.045	0.018	0.046
Maternal heritability	0.494	0.249	0.129	0.091	0.080
s.e.	0.487	0.071	0.068	0.012	0.123
Covariance as proportion of total variance	-0.365	-0.272	-0.144	-0.071	-0.036
s.e.	0.250	0.055	0.049	0.016	0.070
Permanent maternal environment	0.089	0.162	0.137	0.100	0.070
SE	0.330	0.048	0.030	0.009	0.088
Direct additive variance	2.052	3.695	3.495	4.496	3.610
Maternal additive variance	3.755	2.510	1.619	2.216	2.504
Variance due to permanent maternal environment	0.676	1.638	1.717	2.418	2.199
Covariance between animal effects	-2.776	-2.748	-1.819	-1.727	-1.132
Error variance	3.889	5.005	7.562	16.912	24.126
Phenotypic variance	7.597	10.100	12.574	24.315	31.307
Correlation between animal effects	-1.000	-0.901	-0.765	-0.547	-0.376

Many results have been reported for weaning weight in sheep, but very few have been reported for 36-day, 42-day, 50-day and 150-day weight. Only weaning weight was analyzed in the two previous studies conducted with this breed (Neser *et al.*, 1998; Gray *et al.*, 1999). Both the direct and maternal heritability estimates obtained for weaning weight in this study are lower than that reported in the two previous studies (0.19 *vs*. 0.35 and 0.32, and 0.09 *vs*. 0.17 and 0.15). Published South African heritability estimates for weaning weight in other breeds vary from 0.11–0.33 for direct and 0.07–0.20 for maternal effects (Van Wyk *et al.*, 1993; Neser *et al.*, 1995; Snyman *et al.,* 1995). Other published heritability estimates for weaning weight in mutton and dual purpose breeds vary between 0.05 and 0.57 (Fogarty, 1995).

Only four references for 50-day weight could be found (Shrestha *et al.*, 1985; Shrestha *et al.*, 1986; Tosh & Kemp, 1994; Mousa *et al.*, 1999). The heritability estimates (0.28-direct; 0.13-maternal) obtained in this study are agreement with previously published results which vary from 0.05-0.47 for direct and 0.06-0.14 for maternal effects (Shrestha *et al.*, 1985; Shrestha *et al.*, 1986; Tosh & Kemp, 1994; Mousa *et al.*, 1999). They are, however, lower than those obtained by Maria *et al.* (1993) for 60-day weight (0.34-direct; 0.25-maternal) but higher than those obtained by Notter (1998) in Suffolk and Polypay sheep (0.14 and 0.08-direct; 0.05 and 0.07-maternal).

Although it is generally regarded by many that the 42-day weight of a lamb is an indication of the milk production of its dam, the low maternal heritability (0.25) in comparison with the direct heritability (0.37) could be an indication that this assumption is flawed. It seems as if 36-day weight could be a better indicator (0.27) of direct and (0.49) maternal heritability. It should, however, be noted that the standard error estimate for the maternal heritability estimate is high (0.49). These estimates are higher than the direct heritability estimate obtained by Boujenane & Kerfal (1990) for 30-day weight in D’man sheep (0.23). They are also higher than the estimates obtained by Hagger (1998) for Black-Brown Mountain Sheep and White Alpine Sheep (0.16 and 0.14-direct; 0.06 and 0.10-maternal)

Only one South African study deals with 150-day weight. Snyman *et al.* (1995) obtained a direct heritability estimate of 0.38 and a maternal heritability of 0.17 for Afrino sheep. This is higher than the results obtained in this study (0.12 and 0.08 respectively). Other authors only reported direct heritabilities for 180 day weights, which vary from 0.22–0.43 (Dzakuma *et al.*, 1978; Atkins, 1986; Boujenane & Kerfal, 1990).

The covariance between the animal effects was either significant ($P \leq 0.1$) or highly significant ($P \leq 0.01$) in all cases except for 150-day weight, which was non-significant. The genetic correlation estimates between animal effects (direct and maternal) were generally high and negative. As expected, they also declined with age. This corresponds with results obtained by Tosh & Kemp (1994) in Polled Dorset and Romanov sheep. The high negative correlation estimates between the animal effects in all the traits are of concern, as this will hamper selection progress for all these traits. Lee *et al.* (2000) cites a poor pedigree structure that is inadequate for obtaining estimates of both direct and maternal heritabilities and the genetic correlation between the animal effects, as a possible cause of a high negative correlation. He obtained correlation estimates of between -0.80 and -0.91 in native Korean cattle for yearling weight. It is possible, with the inclusion of sire x flock-year-season interaction, to lower the correlation between the two effects (Meyer, 1997; Hagger, 1998; Neser *et al.,* 1998). However, the data structure prevents the fitting of a sire x flock-year-season effect, as sires are largely nested within flock-year-seasons. The total heritability, defined as the value used to calculate the expected response to phenotypic selection, is 0.00, 0.08, 0.13, 0.12 and 0.10 respectively for the five traits. Not only is the negative genetic correlation unity (Table 2), but the total heritability estimate for 36-day weight is zero. This would mean that no selection progress for this trait is possible when selection takes place on the phenotypic value of the animal. The only purpose that this trait would therefore serve is to give an indication of the milk production and nursing ability of the ewe. The total heritability estimates for the rest of the traits are also low, but some selection progress is possible.

The South African Mutton Merino is marketed at weaning or as soon as possible thereafter, either to a feedlot or directly to the slaughterhouse. The majority of stud breeders record only weaning (100-day) weights, and therefore select for high weaning weight. It was therefore decided to present the environmental and genetic trends for weaning weight only.

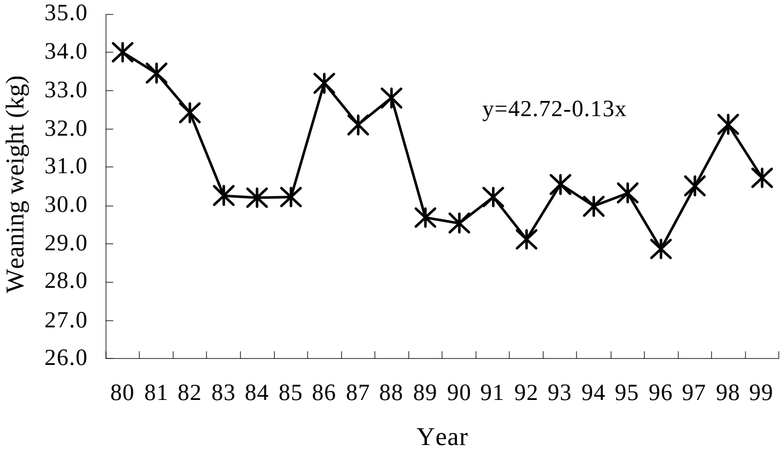

Figure 1 Environmental trends for weaning (100-day) weight in South African Mutton Merinos

The environmental trend for weaning weight is presented in Figure 1. The trend shows a slow but steady decline (b=-0.13) over the evaluation period. The graph generally follows the rainfall pattern during this period.

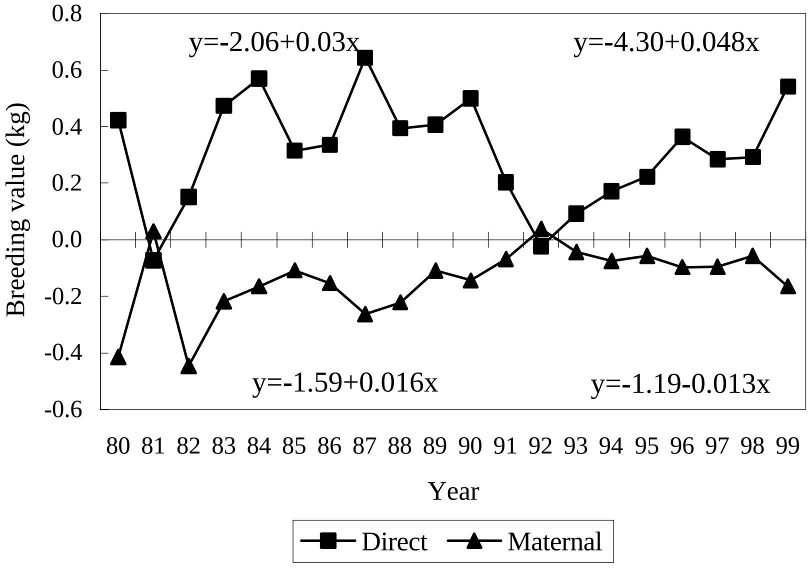

Figure 2 Average direct and maternal breeding values for weaning (100-day) weight in South African Mutton Merinos

The average direct and maternal breeding values are presented in Figure 2. Two distinct time periods (1980-1990 and 1991-1999) are evident. In the first, very few studs contributed to the data set. In the second period, both the number of studs and number of animals per stud showed a substantial increase. It was therefore decided to calculate separate regression lines for each period. Both the first and the second period showed an increase in average direct breeding values over time. The decrease in the average breeding values in 1991 and 1992 could be ascribed to the increase in the number of animals. Data from 1019 animals was recorded in 1989. The number increased to 6315 in 1992 and 9143 in 1995. This could mean that many animals with a lower genetic level entered the evaluation during that time. At the end of the evaluation period, the genetic level of the animals in the study was more or less on par with the animals at the end of the first period. The average maternal breeding values of the animals showed an increase during the first period, but declined slowly during the second period.

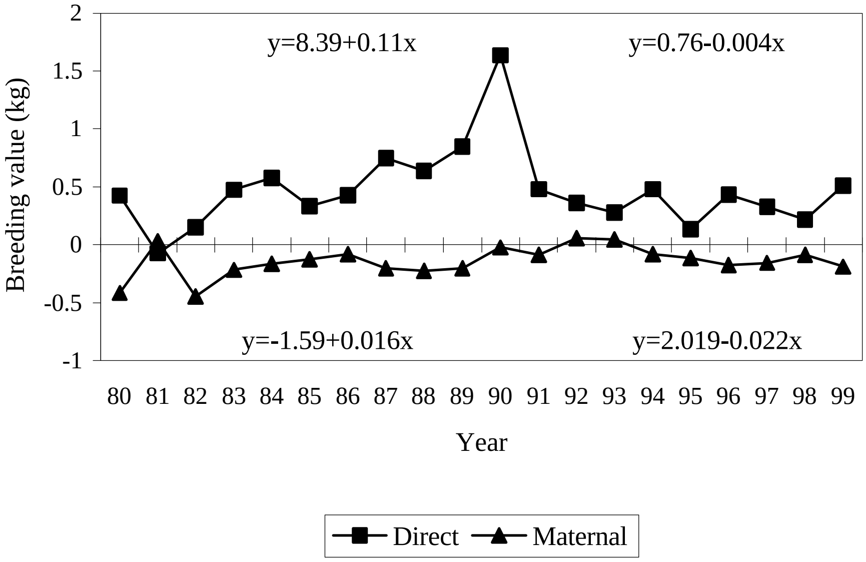

Figure 3 Average direct and maternal breeding values for weaning (100-day) weight in the parent studs of South African Mutton Merinos

In order to overcome the problem of the increase in numbers, it was decided to extract studs contributing at least 20 sires to other studs. The average direct and maternal breeding values of these 14 parent studs are presented in Figure 3. Although an increase in numbers did occur, it was less pronounced than in the breed as a whole. However, it was decided to maintain the two periods. Unfortunately, data from very few animals was recorded in 1990, and this could explain the substantial increase in that year. The first period showed a marked increase in the direct trend (b=0.11). This could be ascribed to the intensive use of a single sire in the majority of the studs during that period. In some years the progeny of this sire accounted for up to 50% of all animals born in the studs. A very small decrease occurred during the second period (b=0.004), which is in contrast with what has happened in the breed as a whole. The parent studs showed virtually no increase over the evaluation period. The average maternal breeding values followed the trends of the breed as a whole.

Conclusion

The limitations of the use of field data in genetic studies have, once again, been illustrated. Breeders record weights at different lamb ages and do not regularly supply all animal records to the database. These studies, however, provide useful information on operational models and genetic parameters based on the actual data needed for predicting breeding values, and is therefore of importance. A structured artificial insemination programme or a sire-referencing scheme will do much to improve the data structure and should be implemented in this breed. The genetic trends are such that they could only inspire greater commitment within the breed society to attain greater progress. The apparent genetic antagonism between these two important causal components of growth needs serious further investigation.

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