GENETIC IMPROVEMENT OF PRODUCTION AND WOOL TRAITS IN THE ELSENBURG MUTTON MERINO FLOCK

by

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CHAPTER 1

GENERAL INTRODUCTION

Sheep are believed to be one of the first mammals to be domesticated and are known to be closely associated with man from a very early date. They offer the potential of making an important and continuing contribution to provide food and fibre for a growing world population. Their small size can also be beneficial in arid, mountainous areas and small-farming situations.

Lamb, meat and wool are the three most important products of sheep. The level of production of these products depends on the genes that the animal has inherited from both parents as well as mixture of seasonal and husbandry factors peculiar to the prevailing environment (Lewis & Beatson, 1999). Due to this in addition to providing adequate environment (e.g. feeding, housing) genetic improvement in production and efficiency of mutton and wool traits have been a focus of breeding activity in sheep.

The South African Mutton Merino is a dual-purpose (mutton and wool) sheep breed and was derived (by selection) from the German Merino, which was imported from Germany in the 1930s (Terblanche, 1979). Continuous effort has been made to improve the breed for wool and mutton traits. In any sheep breeding research, the final goal is to provide pertinent estimates of parameters required to construct a genetic improvement plan which leads to improved viability, productivity and profitability. Therefore, in a dual-purpose sheep breed such as the South African Mutton Merino, the aim of the breeding program should be to increase the efficiency of both slaughter lamb and wool production. Under this condition simultaneous selection for more than one trait is necessary and parameters to be estimated should include relationship between traits.

Previous studies on Merinos have reported genetic parameters for weaning weight (Neser *et al.*, 1998; Gray *et al.*, 1999; Neser *et al.*, 2000), and other traits of economic importance (Olivier *et al.*, 1994; Swan & Hickson, 1994; Snyman *et al.*, 1996). Additionally importance of maternal effects in parameter estimation have been reported (Mortimer & Atkins 1994; Hickson *et al.*, 1995; Snyman *et al.*, 1996).

The use of mixed model methodology (Henderson, 1984), has become an important tool in selection programs. Olivier *et al.* (1995) demonstrated that selection response in the Grootfontein Merino Stud was increased substantially when selection was based on BLUP of breeding values. In order to obtain the most accurate estimation of genetic parameters, it is essential that the most suitable model of analysis should be fitted to the data. Nowadays the animal model is the method of choice, as it allows the use of all available information in the genetic evaluation. It is important to identify the different sources contributing to the phenotypic variance for each trait. These include non-genetic effects, direct additive genetic effects, maternal additive genetic effects, maternal permanent and temporary (litter) environmental effects.

The importance of the inclusion of additive maternal effects in the analysis for early growth traits in mutton sheep was discussed in detail by Van Wyk *et al.* (1993b). Selection progress can sometimes be overestimated from the direct heritability alone, when there is a strong maternal component. Negative relationships between direct and maternal effects for birth and weaning weights in sheep have been reported by Burfening & Kress (1993), Maria *et al.* (1993), Van Wyk *et al.* (1993b), Tosh & Kemp (1994) and Lewis & Beatson (1999).

The availability of modern statistical software has simplified the partitioning of variance into components resulting from either direct or maternal effects. These components must be known, for use in the mixed model equations to obtain BLUP of breeding values. The following are reports on maternal variance and heritability estimates for growth and fleece traits in sheep: Khaldi & Boichard, 1991; Burfening & Kress, 1993;

Maria *et al.*, 1993; Van Wyk *et al.*, 1993b; Mortimer & Atkins, 1994; Olivier *et al.*, 1994; Swan & Hickson, 1994; Tosh & Kemp, 1994; Hickson *et al.*, 1995; Mortimer & Atkins, 1995; Vaez Torshizi *et al.*, 1996; Clarke *et al.*, 2000; Neser *et al.*, 2000; Cloete *et al.*, 2001b; 2002).

Genetic and phenotypic parameters are also commonly used to predict correlated response to selection. Estimates of these parameters are also needed for multiple-trait mixed model methods for prediction of breeding values (Erasmus *et al.*, 1990).Numerous genetic and phenotypic correlations for different breeds have been published (Fogarty, 1995). Some of the genetic correlations reported in these studies are highly variable, especially those estimated between fleece weight and body weight at different ages. Shelton (1998) found that most genetic correlations between wool and lamb production traits were small and negative. Other studies have also reported a small and negative genetic correlation between number of lambs born and fleece weight for 2-yr-old Merino ewes but have reported positive correlations at older ages (Kennedy, 1967; Cloete & Heydenrych, 1987).

The objective of this study is to estimate genetic parameters and determine genetic improvement of live weight and wool traits in the Elsenburg SA Mutton Merino stud. The results can be used to construct a viable, practical breeding plan which could be implemented by Mutton Merino stud breeders and commercial producers to increase the productivity of, and income from, their flocks. Information generated by this study could also provide other sheep breeders with additional information, and also could initiate similar studies.

CHAPTER 2

SOUTH AFRICAN MUTTON MERINO BREED AND THE ELSENBURG FLOCK

2.1 History of the breed and the Elsenburg flock

The South African (SA) Mutton Merino is a dual-purpose sheep breed that was developed by selection from the imported German Merino in the 1930s (Terblanche, 1979). It was developed to produce a slaughter lamb at an early age, as well as good quality wool. During the depression era an overproduction of mutton was experienced in South Africa which necessitated the export of the meat. On account of the indigenous type of sheep encountered in South Africa, mainly in the intensive areas and also the well-known Merino type, these carcasses was not very popular on the Smithfield market. For export purposes, it became necessary that the standard of lamb carcasses should be improved considerably. The results of cross-breeding tests were then already known, and raised a question as to the suitability of the Merino as mother ewe. If the problem of over-production of mutton was to be solved by exporting of meat, it became important to find a suitable mother ewe. This problem, as well as the great numbers of Merinos on the grain farms in the winter rain fall area, served as a motivation for the importation of a more intensive breed. The Merino, which could possibly adapt more successfully under drier extensive environments, had to be replaced by a dual purpose breed that would mature earlier and have the ability to thrive more successfully on good winter grazing.

According to Vosloo (1967) the choice of breed for these purposes was made difficult because of the climatic conditions in the winter rainfall area that made specific demands on any sheep breed in the lambing season. Good grazing in the winter is followed by poor conditions in the dry summer months and early autumn. Accordingly, ewes have to lamb in the autumn and the lambs have to be market ready before the grazing becomes scarce again. In the light of this, various mutton breeds and Mutton Merino crossings were tested at Elsenburg (Conroy, 1961). Among these breeds were Corriedale, Romney

Marsh, South Down, Suffolk Down, Dorset horn, German Merino, Texel and others. Only two of these breeds (Dorset Horn and the German Merino) were able to achieve high lambing percentage in autumn. The German Merino was chosen because of its better wool production and resistance to disease (Conroy, 1961). It also proved to be relatively well adapted to South African conditions especially in the grassland areas.

A recommendation that the German Merino should be imported to South Africa was made in 1930 by Mr.G.J Schuurman, sheep-and-wool officer of the Department of Agriculture at the time. Accordingly 10 ewes and a ram were imported to South Africa by the Department of Agriculture for experimental purposes. Since then German Merinos were imported on several occasions by the state and also by private breeders. According to Vosloo (1967) 6 rams and 38 ewes were imported for the Elsenburg stud from 1932 till 1954, whilst no genetic material migrated from Germany to this stud since then. The first sheep for private breeders were imported in 1934 for Messrs Shady and Kiessig. Afterwards further importation followed for the Eksteen Bros. of Piketberg as well as Messrs Kiessig and Van Zyl of Philippolis and Springfontein in the Southern Free State respectively.

Within the relatively short period of 15 years the German Merino took hold in South Africa to such an extent that a breeder's society was founded on 30th October 1946. The first application for affiliation to the Stud Book was refused in 1932, but the Breed Society was accepted in 1951 by the South African Stud Book Association. As a result of the original small number of animals in the breed, an appendix section was opened early on. According to this, ewes could be chosen for inclusion in Appendix A. By means of mating these ewes with a registered ram the progeny could be registered in Appendix B after intensive selection. Such B ewes could then, in the same manner, be mated with a registered ram, so that this progeny could after inspection then be registered in Appendix C. By means of repeating this procedure, it was possible to take the progeny of Appendix D-ewes into the Stud Book. This process of grading–up was of a great benefit to the breed, especially with reference to increase in numbers. In some established breeds, even foreign genetic material are added by similar methods to the genetic pool of the breed in order to counter-act the weakening of the genetic pool as the result of inbreeding. It is however, not a very effective method, seeing that the D-ewe in such a case possesses only 6.25 percent foreign genes. As a result of sufficient numbers, the registration of ewes in Appendix A was closed in December 1954. However, the registration in Appendix Sections B, C, and D continued until 1963.

In view of the great difference in the climate of Germany compared to South Africa the German Merino at that time had to develop in such a manner as to adapt to the intensive, semi-intensive and even extensive farming conditions in South Africa. The conformation was still left to be desired, while the short dry and yellow wool also undergo a major change. In due course a Mutton Merino came into existence which was reasonably suitable for the purpose for which it was bred and at the same time differed quite a lot from the original German Merino, especially in regard to its wool. A new name for this breed the name " South African Mutton Merino" was adopted by the breeders in August 1970.

The breed is known for its fertility. Ewes produce an average of 3.4 to 4.5 kg wool and rams between 4.5 and 6.0 kg. The clip is a medium to strong white wool which is over-crimped in comparison to Merino wool of the same diameter. SA Mutton Merino wool measures on average between 22 and 23 microns without kemp fibres. The SA Mutton Merino is an efficient feed converter and popular in feedlot production systems, because of its ability to utilize low quality roughage. It is non-selective in its grazing habits and causes no trampling of pastures. This efficiency in energy utilization leads to increased wool and mutton production. The breed is therefore very popular in the grain producing areas of South Africa. It also excels under all climatic conditions and is known for its strong constitution. It is therefore popular in cross-breeding programs with other woolen sheep breeds utilizing the conformation, hardiness, fertility and adaptability of the SA Mutton Merino. The breed has contributed to the development of three other breeds in South Africa, namely the Dormer, Döhne Merino and Afrino. Due to the many animals available, high selection pressure can be maintained in order to improve the South African flock (Campher *et al.,* 1998).

2.2 Description of the environment

The Elsenburg farm is situated in the Boland subregion of the Winter Rainfall Region about 50 km east of Cape Town and 10 km north of Stellenbosch at an altitude of approximately 177 m above sea level, longitude 18° 50-'E and latitude 33° 51-'S. The climate is generally mild with maximum average summer temperatures *ca.* 29° C and minimum winter temperatures *ca.* 7° C. The average annual precipitation of 605.8 mm falls mainly in winter.

2.3 Management of the stud

In general the self-replacing flock was mated in single sire groups to seven dams during October-November, to lamb in March-April. Mating and lambing took place on irrigated kikuyu (Pennisetum clandestinum) pastures, subdivided into units of approximately 0.5 ha each. The breeding flock was maintained on dry-land lucerne (*Medicago sativa*) or oats (*Avena sativa*) pastures during winter and spring, and on irrigated kikuyu paddocks of 1.5-2.0 ha during the dry summer months. From four weeks of age until weaning all lambs received commercial lamb creep feed pellets. Ewes lambed in full fleece, being crutched ± 4 weeks before lambing. This was discussed in detail by Vosloo (1967), Kritzinger *et al.* (1984) and Cloete (1992).

CHAPTER 3

GENETIC PARAMETER ESTIMATES FOR PREWEANING GROWTH TRAITS

3.1 Introduction

Genetic improvement in a breeding program depends on the accuracy of identifying genetically superior animals. For this, important non-genetic sources of variation must be identified and statistically eliminated and genetic parameters estimated.

The availability of modern statistical software has simplified the partitioning of variance into components resulting from either direct or maternal effects. Hence, these components must be known for use in the mixed model equations to obtain BLUP of breeding values, thereby achieve pertinent genetic improvement. This in turn requires the use of appropriate analytical models.

The purposes of this study were first to analyze the records and investigate the effect of non-genetic factors such as sex, birth status, year, age of dam, and weaning age on the different growth traits in the Elsenburg Mutton Merino flock. Secondly, to determine the most effective model for the analysis of the preweaning growth traits. Thirdly to estimate (co)variance components and genetic parameters for each of these traits using the 'best' model.

3.2 Materials and methods

3.2.1 Data

Data used were collected from 1955 to 1999. Before editing the data consisted of 10840 records, the progeny of 255 sires and 1898 dams. For each of the lambs, full pedigree records were available. Traits analyzed were birth (BWT) and weaning weight (WWT).

Data were edited to exclude incomplete records and records of stillborn lambs. No records were available for the year 1967, but pedigrees of parents born in that year were available. Dam ages of higher than seven and birth status higher than three have been coded to seven and three respectively, before the analysis. The final data set included 10717 birth weight (BWT) and 7795 weaning weight (WWT) records. About 30% of the dams had one lambing record, 60% had two to five lambing records and 10% had six to 10 lambing records. A description of the data used in the analyses is given in Table 3.1.

Table 3.1 Description of data used after editing

Traits	No. of Observations	Mean ± SD(kg)	CV(%)	Range
BWT	10717	4.2 ± 0.91	21.7	1.50 - 7.00
WWT	7795	27.5 ± 6.1	22.2	9.50 - 46.0

SD = Standard deviation; CV= Coefficient of variation

3.2.2 Statistical analysis

The statistical analysis consisted of two consecutive steps. Firstly, the significance of the fixed effects was tested, using the GLM procedure of SAS (1994). Only significant effects were kept in the final genetic analysis.

The model fitted was as follows:

$$Y_{ijklm} = \mu + s_j + b_k + d_l + r_m + b_x + e_{ijklm}$$

Where Y_{ijklm} =an observation of a trait on the i'th animal of the j'th sex of the k'th birth status of the l'th age of dam of the m'th year of birth.

μ = least squares mean,

s_j = fixed effect of the j'th sex (j= 1,2),

b_k = fixed effect of the k'th birth status (k= 1,2,3+),

d_l = fixed effect of the l'th age of dam (l=2,3,..., 7 and older),

r_m = fixed effect of the year of birth (1955 – 1999),

b_x = regression of weaning age on weaning weight and

e_{ijklm} = random error

The second procedure followed was the estimation of (co) variance components for each trait using the ASREML programme (Gilmour *et al.,* 1999) Univariate animal models were fitted. Eight general forms of the mixed-model equations were fitted and are presented in Table 3.2. Tests of significance of each random effect were performed using the log likelihood ratio tests. An effect was considered to have a significant influence when its inclusion caused a significant increase in log-likelihood, compared to the model in which it was ignored. When –2 times the difference between the log-likelihoods was greater than values of the Chi^2 distribution with one degree of freedom, the effect was considered to have a significant (P<0.01) effect.

Table 3.2 Eight models describing the random effects

Model	Random Effects
1	Animal
2	Animal + PE
3	Animal + Maternal
4	Animal + Maternal + $A\sigma_{am}$
5	Animal + Maternal + PE
6	Animal + Maternal + PE + $A\sigma_{am}$
7	Animal + Maternal + PE + litter
8	Animal + Maternal + PE + litter + $A\sigma_{am}$

Animal = Direct animal effect; Maternal = Maternal effect; PE = Permanent environmental effect due to the dam; Litter = Common (litter) environmental effect; $A\sigma_{am}$ = Covariance between animal and maternal effect.

Direct and maternal effects were assumed to be normally distributed with mean 0 and variances $A\sigma^2_a$ and $A\sigma^2_m$, respectively. Where A is the numerator relationship matrix and

σ^2_a and σ^2_m are direct additive and maternal additive variances respectively. Permanent maternal environment, litter and residual effects were assumed to be normally distributed with mean 0 and variances $Id\sigma^2_{PE}$, $Ig\sigma^2_{li}$ and $In\sigma^2_e$, respectively, where Id, Ig and In are identity matrices with orders equal to the number of dams, lambings and records respectively, and σ^2_{PE}, σ^2_{li} and σ^2_e are permanent maternal environment, litter and residual variances respectively. Genetic and environmental parameters were estimated as direct additive, maternal additive, permanent maternal environment, and litter variances expressed as proportions of phenotypic variance (h^2_a, h^2_m and PE).

3.3 Results and discussion

3.3.1 Non genetic factors

The results of the analysis of the non-genetic factors affecting birth and weaning weight are presented in Table 3.3. Sex, birth status, age of dam, and birth year had a significant ($P < 0.001$) influence on both birth and weaning weight. The regression of weaning age on weaning weight was also significant.

Table 3.3 Model specification for birth weight (BWT) and weaning weight (WWT)

Source of variation.	DF	BWT	WWT
Sex	1	**	**
Birth status	2	**	**
Age of dam	5	**	**
Year	43	**	**
Weaning age	1	-	**
R-Square	-	33.52	42.46

**P<0.001; DF = Degrees of freedom

Least-squares means and the coefficient of variation (CV%), are presented in Table 3.4. Ram lambs were heavier than ewe lambs at birth and remained heavier till weaning. The

0.3 kg (6.7%) difference recorded at birth increased to 2.4 kg (8.3%) at weaning. These differences in body weight between ram and ewe lambs agreed with the means calculated for several other South African sheep breeds (Van Wyk *et al.*, 1993a; Neser *et al.*, 1995; Snyman *et al.*, 1995a; Neser *et al.*, 2000; Cloete *et al.*, 2001).

Birth and weaning weight generally increase with an increased ewe age. Birth weight increased with age of dam from 2-4 years and remained constant till age 7 years and above. Literature findings indicate that there is no consistent pattern in different breeds and flocks for the effect of age of dam on birth weight. An increase in birth weight was observed up to an age of four years in SA Mutton Merino ewes (Vosloo, 1967) which is in accordance with results of the present study. In Bikaneri ewes (Chopra & Acharya, 1971) and Merino ewes (Heydenrych, 1975; Schoeman, 1990) the increase is up to five years, while it is up to six years of age in Merino and Dormer ewes. In a different study, the birth weight increased up to seven years in Döhne Merino ewes (Fourie & Heydenrych, 1982). The average weaning weight of lambs increased with age of dam up to four years and then decreased from age 5-7 years. The heaviest lambs were from 3-4-year-old dams and the lightest from 7 years and above. These results are in agreement with the findings of Mavrogenis (1988) and Snyman *et al.* (1995a).

Singles were 0.7 kg heavier than twins and 1.4 kg heavier than the triplets at birth and 5.2 kg and 6.9 kg heavier at weaning respectively. These differences correspond to the values found in the literature for different sheep breeds (Shrestha & Vesely, 1986; Cloete & de Villiers, 1987; Mavrogenis, 1988; Boujenane *et al.*, 1991a; Van Wyk *et al.*, 1993a; Neser *et al.*, 1995; Snyman *et al.*, 1995a; Neser *et al.*, 2000; Cloete *et al.*, 2001b).

Table 3.4 Least squares means (LS) and standard errors (SE) and coefficient of variation (CV%) for birth weight (BWT) and weaning weight (WWT)

Effects	BWT (kg)	WWT (kg)
Overall mean	4.2 ± 0.11	18.7 ± 1.73
CV%	16.40	16.77
Sex		
Ram	4.5 ± 0.13	28.8 ± 0.92
Ewe	4.2 ± 0.13	26.4 ± 0.92
Birth status		
1	5.0 ± 0.18	31.6 ± 0.12
2	4.3 ± 0.10	26.4 ± 0.70
3	3.6 ± 0.30	24.7 ± 0.17
Age of dam		
2	3.9 ± 0.18	27.1 ± 0.12
3	4.3 ± 0.17	28.4 ± 0.12
4	4.4 ± 0.18	28.4 ± 0.13
5	4.4 ± 0.21	27.9 ± 0.15
6	4.4 ± 0.25	27.4 ± 0.18
7+	4.4 ± 0.30	26.3 ± 0.19

3.3.2 Random effects

In Tables 3.5 and 3.6 the log likelihood values, variance and parameter estimates obtained under the eight different models are summarized. Published heritability estimates for WWT are also summarized in Table 3.7.

The 'best' model for BWT was found to be Model 8, while for weaning weight Model 7 was found to be the 'best'. Model 7 included the direct genetic, maternal genetic, permanent environmental, litter and the residual effect while model 8 was the same as model 7 but has the genetic covariance between direct and maternal as an additional component.

Litter was included as a component since in this breed a large proportion of multiple births occur; due to this the within litter variance will lead to a small increase in the between litter variance if not included. Therefore, the inclusion of this (litter) component in the model could lead to an improvement in the analysis. The following reports have illustrated this fact (Al-Shorepy & Notter, 1996; Larsgard & Olesen, 1998; Haggar, 1998; Saatci *et al.,* 1999; Lewis & Beatson, 1999). Al-Shorepy & Notter (1996) reported that inclusion of litter effects significantly improved likelihood and also variance was reduced. Haggar (1998) also found that including both maternal permanent and maternal common environment led to improved fit. Saatci *et al.* (1999) discussed that maternal common environment accounted for proportionately 0.20 of the phenotypic variance. The impact of fitting (litter) was greatest on the error variance, reducing its contribution to phenotypic variance by 0.15 compared with the models with out the σ^2_{CE} term. The effect on maternal permanent environmental variance was smaller, reducing its contribution to phenotypic variance by 0.03. Including a maternal common environment effect with out a maternal permanent environment effect tended to inflate m^2 and accounted for 0.20 to 0.27 of the phenotypic variance. These proportions are similar to the 0.26 to 0.31 reported by Haggar (1998) for comparable models.

Table 3.5 Log-likelihood ("best" model in bold) and (co)variance estimates of birth and weaning weight (BWT & WWT) for SA Mutton Merino sheep

Trait		M1	M2	M3	M4	M5	M6	M7	M8
BWT	Log-likelihood	-1685.37	-1373.74	-1323.29	-1321.11	-1304.83	-1302.00	-1163.16	**-1161.08**
	Variance estimates								
	σ^2_p	0.58	0.55	0.58	0.58	0.55	0.55	0.55	**0.54**
	σ^2_a	0.24	0.07	0.05	0.05	0.05	0.05	0.04	**0.04**
	σ^2_m	-	-	0.17	0.19	0.09	0.11	0.09	**0.10**
	σ^2_{pe}	-	0.13	-	-	0.05	0.05	0.04	**0.04**
	σ^2_l	-	-	-	-	-	-	0.11	**0.11**
	σ_{am}	-	-	-	-0.02	-	-0.02	-	**-0.02**
	σ^2_e	0.34	0.35	0.36	0.36	0.36	0.36	0.27	**0.27**
WWT	Log-likelihood	-15696.9	-15651.5	-15651.4	-15650.6	-15643.6	-15642.2	**-15612.9**	-15612.7
	Variance estimates								
	σ^2_p	21.79	21.43	21.80	21.79	21.52	21.52	**21.59**	21.59
	σ^2_a	3.21	1.21	1.01	1.23	0.93	1.09	**0.78**	0.89
	σ^2_m	-	-	2.25	2.67	1.07	1.32	**1.12**	1.30
	σ^2_{pe}	-	2.09	-	-	1.25	1.23	**0.78**	0.77
	σ^2_l	-	-	-	-	-	-	**3.62**	3.61
	σ_{am}	-	-	-	-0.52	-	-0.30	-	-0.21
	σ^2_e	18.58	18.13	18.54	18.41	18.27	18.18	**15.29**	15.23

σ^2_p = Phenotypic variance; σ^2_a = Direct genetic variance; σ^2_m = Maternal variance; σ^2_{pe} = Permanent environmental variance; σ^2_l = Temporary (litter) environmental variance; σ_{am} = Covariance between direct and maternal; σ^2_e = Error variance

Table 3.6 Parameter estimates of birth and weaning weight (BWT & WWT) for SA Mutton Merino sheep

Trait	Parameter estimates	M1	M2	M3	M4	M5	M6	M7	M8
BWT	h^2_a	0.41± 0.02	0.12 ± 0.02	0.08 ± 0.02	0.09 ± 0.02	0.08 ± 0.02	0.10 ± 0.02	0.07 ± 0.02	**0.08 ± 0.02**
	h^2_m	-	-	0.29 ± 0.02	0.33 ± 0.02	0.17 ± 0.02	0.20 ± 0.03	0.17 ± 0.02	**0.20 ± 0.03**
	c^2_{pe}	-	0.24 ± 0.01	-	-	0.09 ± 0.02	0.10 ± 0.02	0.07 ± 0.02	**0.07 ± 0.02**
	c^2_l	-	-	-	-	-	-	0.21 ± 0.02	**0.21 ± 0.01**
	r_{am}	-	-	-	-0.24 ± 0.11	-	-0.04 ± 0.02	0.01 ± 0.11	**-0.28 ± 0.12**
	R	-	0.36 ± 0.02	-	-	-	-	-	-
WWT									
	h^2_a	0.15 ± 0.02	0.06 ± 0.02	0.05 ± 0.02	0.06 ± 0.02	0.04 ± 0.02	0.05 ± 0.02	**0.04 ± 0.02**	0.04 ± 0.02
	h^2_m	-	-	0.10 ± 0.01	0.12 ± 0.02	0.05 ± 0.02	0.06 ± 0.02	**0.05 ± 0.02**	0.06 ± 0.02
	c^2_{pe}	-	0.10 ± 0.01	-	-	0.06 ± 0.02	0.06 ± 0.02	**0.04 ± 0.02**	0.04 ± 0.02
	c^2_l	-	-	-	-	-	-	**0.17 ± 0.02**	0.17 ± 0.02
	r_{am}	-	-	-	-0.30 ± 0.18	-	-.025 ± 0.23	-	-0.20 ± 0.26
	R	-	0.15 ± 0.02	-	-	-	-	-	-

h^2_a = Direct heritability ; h^2_m = Maternal heritability ; c^2_{pe} = Permanent maternal environment; c^2_l = Temporary maternal environment; r_{am} = Genetic correlation between animal effects; r = Repeatability

Identification of maternal common environmental effects highlights the importance of the'temporary' maternal effects on lamb growth, associated for example with short-term injury or disease. Identifying of a substantial maternal common environmental effect, also avoids over-emphasizing the maternal permanent environmental effects, which are essentially outside the control of the shepherd, whereas the maternal common environmental effects may be addressed by individual ewe management and care. Lewis & Beatson (1999) reported a substantial proportion of variation (at least 12% and 16%) in hogget live weight and hogget fleece weight respectively was due to temporary environmental effects of the dam.

The direct heritability estimates obtained for both the traits in this study were much lower than values reported by various authors for several sheep breeds world wide (Burfening & Kress, 1993; Maria *et al.*, 1993; Van Wyk *et al.*, 1993b; Tosh & Kemp, 1994; Swan & Hickson, 1994; Mortimer & Atkins, 1995; Vaez Torshizi *et al.*, 1996; Clarke *et al.*, 2000). The reason for this could be the inclusion of both maternal genetic effect and permanent environmental effect and also the high litter effect. The obtained maternal heritability estimate of BWT (0.20) was higher than the direct heritability (0.08), and this result agrees with the literature values (Table 3.9). The estimated maternal heritability value of WWT (0.05) was also higher than the direct heritability (0.04) and was lower than the values (0.14) and (0.12) of Clarke *et al.* (2000). Gray *et al.* (1999) estimated the direct and maternal heritability for weaning weight to be 0.32 and 0.15 respectively for a SA Mutton Merino and this was much higher than the estimate in this study. 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.*, 1993b; Neser *et al.*, 1995; Snyman *et al.*, 1995b). Other published heritability estimates for weaning weight in mutton and dual-purpose breeds vary between 0.05 and 0.57 (Fogarty, 1995). Neser *et al.* (2000) reported direct heritability estimates of 0.27, 0.37, 0.28, 0.18 and 0.12, for 36-, 42-, 50-, 100- and 150-day weight respectively in the South African Mutton Merino breed. The reported corresponding maternal heritability estimates were 0.49, 0.25, 0.13, 0.09 and 0.08 respectively. Cloete *et al.* (2001b) reported direct heritability estimates for weaning weight of 0.15 for Merinos, 0.21 for Döhne Merinos and 0.32 for SA Mutton

Merinos. Corresponding maternal variance ratios were estimated at 0.15, 0.30 and 0.24, respectively.

Table 3.7 Summary of published animal model direct additive (h^2_a), maternal (h^2_m) and permanent maternal environment (c^2) variance ratios for weaning weight in sheep

Breed	Variance ratio			Reference
	h^2_a	h^2_m	c^2	
Various	0.09-0.22	0.07-0.48	-	Burfening & Kress (1993)
Romanov	0.34	0.25	0	Maria *et al.* (1993)
Dormer	0.13	0.21	-	VanWyk *et al.* (1993b)
Merino	0.24	0.23	-	Swan & Hickson (1994)
Various	0.14-0.39	0.02-0.19	0.12-0.20	Tosh & Kemp (1994)
Merino	0.19-0.25	0.14-0.23	0.02	Hickson *et al.* (1995)
Merino	0.27	0.11	0.07	Mortimer & Atkins (1995)
Crossbred	0.12	-	0.18	Conington *et al.* (1995)
Crossbred	0.19	0.05	0.15	Hall *et al.* (1995)
Dorper	0.11-0.30	0.07-0.20	-	Neser *et al.* (1995)
Afrino	0.33	0.17	-	Snyman *et al.* (1995b)
Merino	0.14	0.11	0.05	Snyman *et al.* (1996)
Baluchi	0.13-0.19	0.03	0.04-0.07	Yazdi *et al.* (1997)
Dőhne Merino	0.06	-	0.21	Cloete *et al.* (1998b)
SAMM	0.13-0.35	0.17	0.07	Neser *et al.*(1998)
Various	0.2-0.27	0.03-0.04	0.39-0.41	Clarke *et al.* (1998)
Crossbred	0.12	0.17	0.10	Larsgard & Olesen (1998)
Various	0.15-0.21	0.04-0.12	0.06-0.13	Notter (1998)
SAMM	0.32	0.15	0.07	Gray *et al.* (1999)
Coopworth	0.03-0.04	0.04-0.15	0-0.09	Lewis & Beatson (1999)
SAMM	0.14-0.19	0.09-0.20	0.10	Neser *et al.* (2000)
Dual-purpose flock	0.14	0.12		Clarke *et al.* (2000)

SAMM = South African Mutton Merino

The obtained permanent maternal environment estimate (0.07) for BWT is lower than that of 0.10 obtained by Maria *et al.* (1993), 0.27 to 0.37 reported by Tosh & Kemp

(1994), but higher than that of 0.02 estimated by Swan & Hickson (1994) and 0.04 estimated by Cloete *et al.* (2001).

A negative genetic correlation of -0.28 was estimated between direct and maternal additive effects for birth weight. This estimate is in agreement with other negative values reported for sheep (Khaldi & Boichard , 1991; Burfening & Kress, 1993; Maria *et al.*, 1993; Van Wyk *et al.*, 1993b; Tosh & Kemp, 1994; Vaez Torshizi *et al.*, 1996; Clarke *et al.*, 2000). Schoeman *et al.* (1997) also reported correlation values of –0.31 and –0.15 for birth and weaning weight respectively in Boer goat. Notter & Hough (1997) and Lewis & Beatson (1999) reported on the disadvantage of a high negative correlation between direct and maternal effects in sheep. Gray *et al.* (1999) and Neser *et al.* (2000) reported a negative correlation between direct and maternal effects for weaning weight in south African Mutton Merino sheep. Cloete *et al.* (2001) also reported negative and fairly high correlation between direct and maternal effects for weaning weight in Döhne Merino and South African Mutton Merino sheep.

3.4 Conclusions

The results obtained in this study confirm the importance of the non-genetic factors as sources of variation in body weight traits of Mutton Merino sheep. They indicate the importance of adjusting for these non-genetic factors and they should be included in an operational model fitted for the estimation of genetic parameters or breeding values for Mutton Merino sheep.

This study also showed the importance of maternal effect on both the traits (BW, WWT) studied. Under this situation, if the maternal effect is not considered it leads to an overestimation of the direct heritability. Also, the exclusion of the maternal permanent and temporary (litter) environmental effects could bias the estimates of the maternal heritabilities. The moderate negative genetic correlation indicates that the selection program should incorporate both direct and maternal breeding values.

CHAPTER 4

PHENOTYPIC AND GENETIC PARAMETER ESTIMATES FOR YEARLING BODY WEIGHT AND WOOL TRAITS

4.1 Introduction

When a species produces more than one commodity, such as meat and wool, benefits from genetic responses are expressed as increased profitability due to improvement in wool production, reproductive ability and lamb weight (Sakul *et al.*, 1994). For estimating selection response reliable estimates of genetic parameters are needed. Besides heritabilities and variation of each trait, a knowledge of how selection for one trait will influence others is also crucial, because unfavorable correlated responses could render improvement in a specific trait undesirable as far as total economic value is concerned. Also, if genetic improvement in a trait does not increase efficiency of production, it is not considered of economic importance. Therefore, the purpose of this study was:

1. To estimate genetic parameters for yearling body weight and wool traits.
2. To investigate phenotypic, genetic and environmental correlations among yearling body weight and wool traits in an effort to quantify how improvement in any one trait will affect the other traits.

4.2 Material and methods

4.2.1. Data

Data for this study were obtained from the Elsenburg S.A. Mutton Merino Stud. Data on yearling body weight and wool traits were collected from 1983 to 1999. Traits analyzed were yearling weight (YRWT), greasy fleece weight (GFW), clean fleece weight (CFW) and mean fiber diameter (MFD).

After editing the following data sets were available for use in the analysis; namely 2021 yearling weight (YRWT) records, 1965 greasy fleece weight (GFW), clean fleece weight (CFW) and mean fiber diameter (MFD) records respectively. The fleece weight were adjusted to 365 days growth. A description of the data is presented in Table 4.1.

Table 4.1 Description of data used

Traits	No. of observations	Mean ± S.D	CV(%)	Range
YRWT (kg)	2021	50.8 ± 9.7	19.16	25.0-86.0
GFW (kg)	1965	3.4 ± 0.92	27.20	1.04-7.70
CFW (kg)	1965	2.2 ± 0.56	25.37	0.70-4.70
MFD (μm)	1965	23.1 ± 1.68	7.27	17.1-30.2

S.D= Standard deviation; CV= Coefficient of variation

4.2.2 Statistical analysis

The statistical analysis consisted of three consecutive steps. Firstly, the significance of fixed effects were tested using the GLM procedure of SAS (1994).

A summary of the fixed effects tested is given in Table 4.2. The following model was fitted:

$$Y_{ijklm} = \mu + s_j + b_k + d_l + r_m + e_{ijklm}$$

Where Y_{ijklm} =an observation of a trait on the i'th animal of the j'th sex of the k'th birth status of the l'th age of dam of the m'th year of birth.

μ = least squares mean,

s_j = fixed effect of the j'th sex (j= 1,2),

b_k = fixed effect of the k'th birth status (k= 1,2,3),

d_l = fixed effect of the l'th age of dam (l=2,3,..., 7 and older),

r_m = fixed effect of the year of birth (1983 – 1999) and

e_{ijklm} = random error of the environment.

The second procedure followed was the estimation of (co)variance components for each trait using the ASREML programme (Gilmour *et al.,* 1999) fitting univariate animal models (see 3.2.2).

The third procedure followed was the calculation of genetic correlations using bivariate analyses.

4.3 Results and discussion

4.3.1 Non genetic factors

Results of the analysis of the non-genetic factors affecting the yearling weight and the wool traits are presented in Table 4.2. Sex had a highly significant ($P < 0.0001$) influence on YRWT, GFW and CFW, but not on MFD. Birth status had a highly significant ($P < 0.0001$) influence on YRWT, GFW, CFW and MFD. Age of dam had only a significant ($P < 0.001$) influence on YRWT. Birth year had a significant ($P < 0.0001$) influence on all the traits.

Table 4.2 Model specification for yearling weight and wool traits

Source of variance	DF	YRWT	GFW	CFW	MFD
Sex	1	***	***	***	NS
Birth status	2	***	***	***	**
Age of dam	5	**	NS	NS	NS
Year	16	***	***	***	***
R-Square	-	77.68	67.08	55.43	33.96

***P<0.0001; **P<0.001; DF = Degrees of freedom; NS= Non-significant

Least squares means, standard errors and coefficient of variation of the different traits are presented in Table 4.3. Ram lambs had a heavier YRWT than ewes with a difference of 10.6 kg. Similar difference in body weight between ram and ewe lambs were recorded for several other South African sheep breeds (Heydenrych, 1975; Fourie &Heydenrych, 1982; Cloete & de Villiers, 1987; van Wyk *et al.,* 1993a; Neser *et al.,* 1995; Snyman *et al.,* 1995a; Neser *et al.,* 2000).

Single born lambs had heavier YRWT than the twins and triplets and were 3.3kg and 4.7kg heavier than the twins and the triplets respectively. This agrees with the documented work for different sheep breeds (Fourie & Hedenrych, 1982; Shrestha & Vesely, 1986; Cloete & de Villiers, 1987; Mavrogenis, 1988; Boujenane *et al.,* 1991a; Van Wyk *et al.,* 1993a; Neser *et al.,* 1995; Snyman *et al.,* 1995a; Neser *et al.,* 2000).

Table 4.3 Least squares means (LS) and standard errors (SE) and coefficient of variation (CV%) for yearling weight (YRWT), greasy fleece weight (GFW), clean fleece weight (CFW) and mean fiber diameter (MFD)

Effects	YRWT(kg)	GFW(kg)	CFW(kg)	MFD(μm)
Overall mean	51.4 ± 0.16	3.37 ± 0.18	2.19 ± 0.12	23.1 ± 0.04
CV%	9.14	15.77	17.11	5.96
Sex				
Ram	56.7 ± 2.09	3.6 ± 0.24	2.3 ± 0.37	23.4 ± 1.3
Ewe	46.1 ± 1.81	3.2 ± 0.21	2.1 ± 0.36	23.0 ± 1.2
Birth status				
1	54.0 ± 2.68	3.5 ± 0.30	2.3 ± 0.40	22.8 ± 1.4
2	50.7 ± 1.53	3.4 ± 0.17	2.2 ± 0.35	23.1 ± 1.2
3	49.3 ± 3.40	3.3 ± 0.39	2.1 ± 0.43	23.2 ± 1.4
Age of dam				
2	51.5 ± 2.86	3.2 ± 0.46	2.2 ± 0.41	22.9 ± 1.4
3	52.0 ± 2.60	3.3 ± 0.44	2.2 ± 0.39	23.0 ± 1.3
4	51.8 ± 2.67	3.3 ± 0.48	2.2 ± 0.39	23.0 ± 1.4
5	51.4 ± 3.10	3.3 ± 0.48	2.2 ± 0.42	23.0 ± 1.4
6	51.2 ± 3.70	3.3 ± 0.53	2.2 ± 0.46	23.0 ± 1.6
7+	50.3 ± 4.00	3.2 ± 0.56	2.2 ± 0.47	23.1 ± 1.6

Yearling weight (YRWT) increased with an increase of age of ewe untill year-3 and decreased slowly thereafter. The GFW of rams were 0.4kg heavier than that of ewes. Single born had heavier GFW than the rest. GFW increased with age untill about year-6 after that it declined. The CFW of rams were 0.2kg heavier than that of ewes. with a difference of 0.2kg. CFW was consistent with age difference and singles had heavier CFW than the rest. This agrees with the results of Snyman *et al.* (1996). Rams had better (finer) MFD than ewes and the difference was 0.4μm. This agrees with the results of Snyman *et al.* (1996). Single born had finer MFD than the twins and triplets and the difference was 0.3μm and 0.4μm respectively. MFD was almost consistent with the age of dam.

4.3.2 Random effects

In Table 4.4 the log likelihood values obtained under the eight different models of analysis are summarized. The 'best' model for YRWT was model 6 and for GFW was model 2, while model 3 was 'best' for CFW and model 1 for MFD.

The estimates of direct and maternal heritability and proportion of maternal environmental components as that of the total phenotypic variance components are presented in Tables 4.5-4.6; while a summary of published animal model direct additive (h^2) and maternal (m^2) variance ratios for liveweight and fleece traits at yearling and/or two-tooth age in sheep are presented in Tables 4.7 and 4.8. The direct heritability estimate obtained for YRWT in this study (0.18) was much lower than values reported by various authors for several sheep breeds world wide (Table 4.7). Cloete *et al.* (2001b) reported direct heritability values of 0.30, 0.33, and 0.45 for YRWT in Merinos, Döhne Merinos and South African Mutton Merinos, respectively. Fogarty (1995) reported mean heritabilities of 0.25, 0.31 and 0.57 for hogget liveweight for meat, dual-purpose and wool breeds respectively. Brash *et al.* (1994a, 1994b and 1994c) reported 0.24, 0.13, and 0.38 for liveweight and yearling weight in the Australian Border Leicester, Corriedale and Coopworth sheep respectively. The maternal heritability estimate obtained for YRWT in this study was much higher than values reported by several authors (see Table 4.7). It was however, lower than estimates reported by Swan & Hickson, (1994), Hickson *et al.* (1995) and Clarke *et al.* (2000). The later report was for hogget liveweight in dual-purpose sheep of New Zealand.

Table 4.4 Log-likelihoods for yearling weight and wool traits under eight different models with the 'best' model in bold

Model	YRWT	GFW	CFW	MFD
1	-4082.73	253.00	918.85	**-1433.33**
2	-4074.92	**256.08**	922.95	-1433.30
3	-4074.71	255.53	**922.18**	-1432.55
4	-4073.79	256.76	923.14	-1431.75
5	-4073.78	256.29	923.18	-1432.55
6	**-4072.18**	NC	NC	-1431.75
7	-	NC	NC	-1431.93
8	-	NC	NC	-1431.04

NC= No convergence

The direct heritability estimates obtained for GFW (0.39) and CFW (0.37) in this study were much higher than values reported by various authors for several sheep breeds world wide (see Table 4.8). Fogarty (1995) reported mean heritabilities of 0.35 and 0.36 for GFW and CFW respectively. Brash *et al.* (1994a, 1994b, 1994c & 1994d) reported 0.17, 0.32, and 0.28 for GFW of Australian Border Leicester, Corriedale and Coopworth sheep respectively. Clarke *et al.* (2000) reported heritability estimates of 0.36 for Hogget live weight of dual-purpose sheep of New Zealand. Brash *et al.* (1994b) also reported 0.29 for CFW of Australian Corriedale sheep.

Table 4.5 Log-likelihood ("best" model in bold) and (co)variance estimates of yearling weight (YRWT) and wool traits (GFW&CFW) for SA Mutton Merino sheep

Trait		M1	M2	M3	M4	M5	M6	M7	M8
YRWT	Log-likelihood	-4082.73	-4074.92	-4074.71	-4073.79	-4073.78	**-4072.18**	-	-
	Variance estimates								
	σ^2_p	22.56	22.14	22.44	22.37	22.23	**22.16**	-	-
	σ^2_a	6.74	4.69	4.51	5.53	4.41	**5.61**	-	-
	σ^2_m	-	-	2.06	3.17	1.09	**2.06**	-	-
	σ^2_{pe}	-	1.84	-	-	1.0	**1.23**	-	-
	σ^2_1	-	-	-	-	-	-	-	-
	σ_{am}	-	-	-	1.65	-	**-1.78**	-	-
	σ^2_e	15.82	15.61	15.87	15.32	15.73	**15.04**	-	-
GFW		253.00	**256.08**	255.53	256.76	256.29	NC	258.82	NC
	σ^2_p	0.31	**0.31**	0.30	0.28	0.30	-	0.31	-
	σ^2_a	0.14	**0.12**	0.11	0.08	0.11	-	0.11	-
	σ^2_m	-	-	0.02	0.002	0.01	-	0.01	-
	σ^2_{pe}	-	**0.02**	-	-	0.01	-	0.01	-
	σ^2_1	-	-	-	-	-	-	0.03	-
	σ_{am}	-	-	-	0.01	-	-	-	-
	σ^2_e	0.17	**0.17**	0.17	0.19	0.17	-	0.15	-
CFW		918.85	922.95	**922.18**	923.14	923.18	NC	924.21	NC
	σ^2_p	0.15	0.15	**0.15**	0.15	0.153	-	0.153	-
	σ^2_a	0.06	0.05	**0.05**	0.04	0.05	-	0.05	-
	σ^2_m	-	-	**0.01**	0.01	0.003	-	0.003	-
	σ^2_{pe}	-	0.01	-	-	0.01	-	0.01	-
	σ^2_1	-	-	-	-	-	-	0.01	-
	σ_{am}	-	-	-	0.01	-	-	-	-
	σ^2_e	0.09	0.09	**0.09**	0.09	0.09	-	0.08	-

Table 4.5 Log-likelihood ("best" model in bold) and (co) variance estimates of MFD for SA Mutton Merino sheep

Trait		M1	M2	M3	M4	M5	M6	M7	M8
MFD	Log-likelihood	**-1433.33**	-1433.30	-1432.55	-1431.75	-1432.55	-1431.75	-1431.93	-1431.04
	Variance estimates								
	σ^2_p	**1.99**	1.99	2.00	2.03	2.00	2.03	1.99	2.04
	σ^2_a	**1.34**	1.34	1.32	1.55	1.32	1.55	1.32	1.57
	σ^2_m	-	-	0.04	0.09	0.04	0.09	0.03	0.08
	σ^2_{pe}	-	0.01	-	-	-	-	-	-
	σ^2_l	-	-	-	-	-	-	0.07	0.70
	σ_{am}	-	-	-	-0.13	-	-0.13	0.57	-0.13
	σ^2_e	**0.65**	0.64	0.64	0.52	0.64	0.52	-	0.45

σ^2_p = Phenotypic variance; σ^2_a = Direct genetic variance; σ^2_m = Maternal variance; σ^2_{pe} = Permanent environmental variance; σ^2_l = Temporary (litter) environmental variance; σ_{am} = Covariance between direct and maternal; σ^2_e = Error varianc

Table 4.6 Parameter estimates of yearling weight (YRWT) and wool traits (GFW, CFW) for SA Mutton Merino sheep

Trait	Parameter estimates	M1	M2	M3	M4	M5	M6	M7	M8
YRWT	h^2_a	0.30 ± 0.05	0.21 ± 0.05	0.20 ± 0.05	0.25 ± 0.07	0.20 ± 0.05	**0.25 ± 0.07**	-	-
	h^2_m	-	-	0.09 ± 0.03	0.14 ± 0.04	0.05 ± 0.04	**0.09 ± 0.05**	-	-
	c^2_{pe}	-	0.08 ± 0.02	-	-	0.05 ± 0.03	**0.06 ± 0.03**	-	-
	c^2_l	-	-	-	-	-	-	-	-
	r_{am}	-	-	-	-0.39 ± 0.18	-	**-0.52 ± 0.19**	-	-
	r	-	0.30 ± 0.05	-	-	-	-	-	-
GFW									
	h^2_a	0.44 ± 0.05	**0.39 ± 0.06**	0.36 ± 0.06	0.28 ±0.00	0.38 ± 0.06	-	0.37 ± 0.06	-
	h^2_m	-	-	0.06 ± 0.03	0.01 ± 0.00	0.02 ± 0.03	-	0.02 ± 0.03	-
	c^2_{pe}	-	**0.05 ± 0.02**	-	-	0.04 ± 0.03	-	0.02 ± 0.03	-
	c^2_l	-	-	-	-	-	-	0.09 ± 0.04	-
	r_{am}	-	-	-	0.99 ± 0.00	-	-	-	-
	r	-	**0.44 ± 0.05**	-	-	-	-	-	-
CFW									
	h^2_a	0.42 ± 0.05	0.37 ± 0.05	**0.34 ± 0.06**	0.29 ± 0.06	0.35 ± 0.06	-	0.35 ± 0.06	-
	h^2_m	-	-	**0.06 ± 0.03**	0.03 ± 0.03	0.02 ± 0.03	-	0.02 ± 0.03	-
	c^2_{pe}	-	0.06 ± 0.02	-	-	0.04 ± 0.03	-	0.34 ± 0.03	-
	c^2_l	-	-	-	-	-	-	0.06 ± 0.04	-
	r_{am}	-	-	-	0.53 ± 0.47	-	-	-	-
	R	-	0.42 ± 0.05	-	-	-	-	-	-

Table 4.6 Parameter estimates of MFD for SA Mutton Merino sheep

Trait	Parameter estimates	M1	M2	M3	M4	M5	M6	M7	M8
MFD	h^2_a	**0.67 ± 0.04**	0.68 ± 0.04	0.66 ± 0.05	0.76 ± 0.09	0.66 ± 0.05	0.76 ± 0.09	0.66 ± 0.05	0.77 ± 0.09
	h^2_m	-	-	0.02 ± 0.02	0.04 ± 0.03	0.02 ± 0.02	0.04 ± 0.03	0.02 ± 0.02	0.04 ± 0.03
	c^2_{pe}	-	0.04 ± 0.02	-	-	-	-	-	-
	c^2_l	-	-	-	-	-	-	0.04 ± 0.03	0.04 ± 0.03
	r_{am}	-	-	-	-0.34 ± 0.20	-	-0.34 ± 0.20	-	-0.38 ± 0.21
	r	-	0.68 ± 0.05	-	-	-	-	-	-

h^2_a = Direct heritability ; h^2_m = Maternal heritability ; c^2_{pe} = Permanent maternal environment; c^2_l = Temporary maternal environment; r_{am} = Direct and maternal covariance; R = Repeatability

The direct heritability estimate obtained for MFD (0.67) in this study was higher than values reported by various authors for several sheep breeds world wide (see Table 4.8). It was also higher than values 0.56 and 0.18 reported by Brash *et al.* (1994b and 1994c) of Australian Corriedale and Coopworth sheep respectively. But it was lower than the values (0.73, 0.75, 0.71) obtained by (Snyman *et al.,* 1995b; Cloete *et al.,* 2001b; Cloete *et al.,* 2002), respectively for Afrino, SA Mutton Merino and Western Australian Merino sheep.

Maternal heritability was lower than direct heritability in YRWT, GFW and CFW. For MFD the maternal component was not important. Maternal effects are usually expressed in weights or traits measured during early life. Thus for a trait like yearling weight it is only the carry over effect that could be expressed.

Table 4.7 Summary of published animal model direct additive (h^2_a) and maternal (h^2_m) variance ratios for live weight at yearling and/or two-tooth age in sheep

Breed	Variance ratio		Reference
	h^2_a	h^2_m	
Merino	0.38	0.01	Olivier *et al.* (1994)
Merino	0.28	0.12-0.14	Swan & Hickson (1994)
Merino	0.33-0.35	0.12	Hickson *et al.* (1995)
Merino	0.33	0.08	Mortimer & Atkins (1995)
Afrino	0.58	0.05	Snyman *et al.* (1995b)
Merino	0.43	0.04	Snyman *et al.* (1996)
Baluchi	0.26-0.32	0.01-0.02	Yazdi *et al.* (1997)
Merino	0.25-0.33	0.05-0.07	Olivier *et al.* (1998)
Dőhne Merino	0.24	-	Cloete *et al.* (1998b)
Targhee	0.21	-	Notter (1998)
Coopworth	0.14-0.45	0.02-0.08	Lewis & Beatson (1999)

Table 4.8 Summary of published animal model direct additive (h^2_a) and maternal (h^2_m) variance ratios for fleece traits at yearling and/or two-tooth age in sheep

Breed	Variance ratio h^2_a	h^2_m	Reference
	Fleece weight		
Merino	0.28-0.35	0.08-0.10	Olivier *et al.* (1994)
Merino	0.29	0.05	Swan & Hickson (1994)
Merino	0.30-0.36	-	Coelli & Atkins (1995)
Merino	0.28-0.34	0.06-0.14	Hickson *et al.* (1995)
Merino	0.28-0.31	-	Swan *et al.* (1995)
Afrino	0.62	-	Snyman *et al.* (1995b)
Merino	0.26	0.04	Snyman *et al.* (1996)
Baluchi	0.24-0.26	0.07	Yazdi *et al.* (1997)
Döhne Merino	0.35	-	Cloete *et al.* (1998)
Polipay	0.44	-	Notter (1998)
Coopworth	0.26	0.02	Lewis & Beatson (1999)
	Fibre diameter		
Merino	0.63	0.01	Olivier *et al.* (1994)
Merino	0.44-0.67	0.01	Swan & Hickson (1994)
Merino	0.58-0.60	-	Coelli & Atkins (1995)
Afrino	0.73	-	Snyman *et al.* (1995b)
Merino	0.60	-	Snyman *et al.* (1996)
Merino	0.44-0.47	0.03-0.04	Olivier *et al.* (1998)
Merino	0.43	-	Cloete *et al.* (1998b)

Estimates of phenotypic and genetic correlations between the different traits is presented in Table 4.9. The phenotypic correlation of yearling weight with fleece weights (GFW, CFW), and MFD were positive and low to medium. This indicates that it is possible to improve the fleece weight by increasing body weight. Phenotypic correlations between

GFW and CFW and MFD were positive and low to high. This indicates that by selecting for GFW one can get similar response in CFW and MFD, but the impact of MFD is very insignificant.

The genetic correlation of yearling weight with fleece weights were positive, indicating that by increasing the YRWT it is possible to improve the fleece weights. The estimated genetic correlation of yearling weight with greasy fleece weight was 0.22. Corresponding genetic correlations reported in the literature for live weight with greasy fleece weight had a mean of 0.21 (Fogarty 1995) and 0.30-0.34 (Brash *et al.,* 1997). The estimated genetic correlation of yearling weight with clean fleece weight was 0.20. The mean literature estimate between live weight and clean fleece weight was 0.18 (Fogarty, 1995), 0.20-0.58 (Brash *et al.,* 1997), 0.37 (Cloete *et al.,* 1998a) and 0.27 (Purvis & Swan 1999). These estimates are consistent with those obtained in the present study.

The genetic relationship of yearling weight with fibre diameter was positive (0.22) and suggested that selection for heavier sheep will probably result in a broader fibre diameter. Corresponding genetic correlations were found in the literature (a mean of 0.10, Fogarty, 1995; 0.13-0.36, Brash *et al.,* 1997; 0.26, Cloete *et al.,* 1998a; 0.18, Purvis & Swan 1999). But on the other hand although the genetic correlation (0.22) indicates that MFD will increase with an increase in YRWT, it is also possible to decrease fibre diameter while increasing body weight. This is because their correlation is very low and selection for one of the trait has no high impact on the other. Thus one can select for both high YRWT and low MFD and improve YRWT while reducing MFD. This was clearly illustrated by the work of Olivier & Erasmus (personnal communication) in the Groofontein fine wool Merino Stud. Greasy fleece weight and clean fleece weight were closely related (0.89), as was also reported in the literature (Brash *et al.,* 1997; Rose & Pepper, 1999). This indicates that selection for either of the traits can improve the other.
Fleece weight was positively related to fibre diameter, suggesting that selection for fleece weight without awareness of fibre diameter will lead to wool in breeding flocks becoming broader. The genetic correlation between clean fleece weight and fibre diameter in the current study (0.36) corresponds with that in literature (a mean estimate

of 0.21, Fogarty, 1995; 0.38-0.51, Brash *et al.,* 1997; 0.47, Taylor *et al.,* 1997; 0.26, Cloete *et al.,* 1998a; 0.14, Purvis & Swan 1999; 0.25, Rose & Pepper 1999).

Table 4.9 Phenotypic (above diagonal) and genetic (below diagonal) correlations and (±SE) between yearling weight and fleece traits

	YRWT	GFW	CFW	MFD
YRWT	-	0.41 ± 0.024	0.37 ± 0.024	0.16 ± 0.027
GFW	0.22 ± 0.129	-	0.62 ± 0.012	0.22 ± 0.028
CFW	0.20 ± 0.135	0.89 ± 0.022	-	0.26 ± 0.027
MFD	0.22 ± 0.113	0.18 ± 0.087	0.38 ± 0.085	-

YRWT= Yearling weight; GFW= Greasy fleece weight; CFW= Clean fleece weight
MFD= Mean fibre diameter

4.4 Conclusions

Medium to high heritability estimates were obtained for YRWT, GFW, CFW and MFD. This entails that selection is likely to result in favorable response. However the values of the yearling weight were much lower than most values in the literature. Therefore, further study using a larger data set is required to confirm the higher heritability of these traits in SA Mutton Merinos.

In this study estimates of genetic correlations were also of particular interest, as they indicate what possible correlated response to selection could be expected. The low and positive estimates between yearling weight and fleece weights indicate that the correlated improvement through selection of the two traits will be low. The high correlation estimates between GFW and CFW indicated that selection for either trait can positively influence the other and the correlated improvement will be high. The positive and moderate estimates between CFW and MFD indicated that selection for one of them can affect the other, which in this case can be seen as an antagonistic relationship.

CHAPTER 5

GENETIC AND ENVIRONMENTAL TRENDS

5.1 Introduction

The main goal of animal breeders is to maximize the rate of genetic improvement through selection. To achieve this goal one has to focus on the accuracy of selecting superior parents for the next generation. To determine the effectiveness of selection, genetic trends in the given population must be monitored. Henderson (1973) described the use of mixed linear models for animal breeding, and this methodology is now being applied in animal genetic evaluation programs worldwide. Since it incorporates all known relationships in the population it is the most effective method of separating genetic and environmental effects. Also maternal genetic effects can be accounted simply by fitting them as additional random effects.

The purpose of this study was to investigate genetic change in early growth and wool traits, by partitioning the phenotypic trend into its causal components i.e. environmental and genetic effects.

5.2 Materials and methods

5.2.1 Data

Data used for this study were collected from Elsenburg SA Mutton Merino sheep stud, collected over the period of 1955 to 1999 (for BWT and WWT only) and from 1983 to 1999 for yearling body weight and fleece traits. Traits considered were birth weight (BWT), weaning weight (WWT) , yearling weight (YRWT), and four fleece traits namely greasy fleece weight (GFW), clean fleece weight (CFW) and fibre diameter (MFD). The number of records were, 10717, 7795, 2021 for BWT, WWT, YRWT and 1965 for the three fleece traits, respectively.

5.2.2 Statistical analysis

Breeding values were obtained using the ASREML (Gilmour, *et al.,* 1999) program. Where applicable both direct and maternal breeding values were predicted using the 'best' model from previous univariate analysis (Chapter 3).

Genetic trends were calculated as the regression of the average predicted breeding values on year of birth.

Different ways of defining and computing environmental trends exist. The most common is to regress the year solution on the year number. This, however, reflects only the year effect and not the total environmental effect, since adjustments are made for known environmental effects. Therefore, it was decided to calculate the environmental trend by subtracting the breeding value from the phenotypic value.

5.3 Results and Discussion

Regression coefficients, standard errors and R^2 of phenotypic, genetic (direct and maternal) and environmental trends in birth, weaning and yearling weights as well as the wool traits are presented in Table 5.1. The genetic (direct and maternal), phenotypic and environmental trends of WWT, CFW and MFD are also illustrated in Figures 5.1a-5.3b.

All the genetic trends, except the maternal component of GFW, were positive while the phenotypic and environmental trends were negative. The linear regressions produced showed varied fits. The direct genetic trends of the different traits had low to high R^2 values which varies between 0.01 to 0.89, while the R^2 values for the maternal genetic trends varies between 0.80 to 0.81. The phenotypic trends of the growth traits had low R^2 values which varies between 0.02 to 0.12. These low values can be ascribed to the fluctuation of the environment.

Over a period of 44 years the phenotypic trend for BWT and WWT decreased by about 0.10 kg and 3.22 kg respectively. The small positive contribution of about 0.013 kg (BWT) and 0.88 kg (WWT) of genetic trend to environmental trend (-0.44 kg and –4.91 kg), helped to counteract a larger decrease in phenotypic trend. In 1994-96 there was a marked decrease of phenotypic and environmental trends, and could be due to unfavorable season, poor grazing and management; and the sharp increase of 1997-99 could be due to the improvement of the above factors.

In YRWT there was a genetic gain of 1.42 kg in 17 years, but due to high loss of environmental trend (16.94 kg) the phenotypic change was also negative (15.39 kg). GFW and CFW (Fig 5.2a) increased genetically by 0.04 kg and 0.08 kg in 17 years respectively, but due to a marked negative environmental trend the phenotypic change was also negative (1.58kg and 0.784kg). Genetically the Elsenburg stud became coarser (higher MFD) (Fig 5.3a) over the last 17 years while a decrease in average phenotypic value (Fig 5.3b) was evident due to a decline in the environment.

In general all environmental and phenotypic trends were negative, while genetic trends in all traits except maternal genetic trend for GFW were positive. The low genetic trends suggest that selection pressure on these traits was low during the 44 years of existence. The higher maternal trends reveal that the biggest genetic improvement was in the additive genetic ability of ewes to produce faster growing or heavier lambs.

Table 5.1. Regression coefficients (b), standard errors (± SE) and R^2 of phenotypic, genetic (direct and maternal) and environmental trends in birth, weaning and yearling weights and the wool traits (1955-1999)

	Component							
Trait	Phenotypic		Genetic (dir)		Genetic (mat)		Environment	
	b	R^2	b	R^2	b	R^2	b	R^2
BWT (kg/yr)	-0.0023 ± 0.0027	0.02	0.0003 ± 0.0004	0.01	0.0076 ± 0.0006	0.81	-0.0101 ± 0.0027	0.26
WWT (kg/yr)	-0.0731± 0.0310	0.12	0.0200 ± 0.0011	0.89	0.0185 ± 0.0014	0.80	-0.1116± 0.0318	0.23
YRWT (kg/yr)	-0.9050 ± 0.2296	0.51	0.0832 ± 0.0099	0.83	0.0084 ± 0.0035	0.28	-0.9967 ± 0.2332	0.55
GFW (kg/yr)	-0.0930 ± 0.0248	0.49	0.0021 ± 0.0029	0.04	-0.0048 ± 0.0036	0.11	-0.0903 ± 0.0264	0.44
CFW (kg/yr)	-0.0461 ± 0.0151	0.38	0.0045 ± 0.0011	0.54	0.0006 ± 0.0005	0.11	-0.0513 ± 0.0154	0.43
MFD (µm)	-0.0705 ± 0.0405	0.17	0.0190 ± 0.0072	0.32	-	-	-0.0895 ± 0.0370	0.28

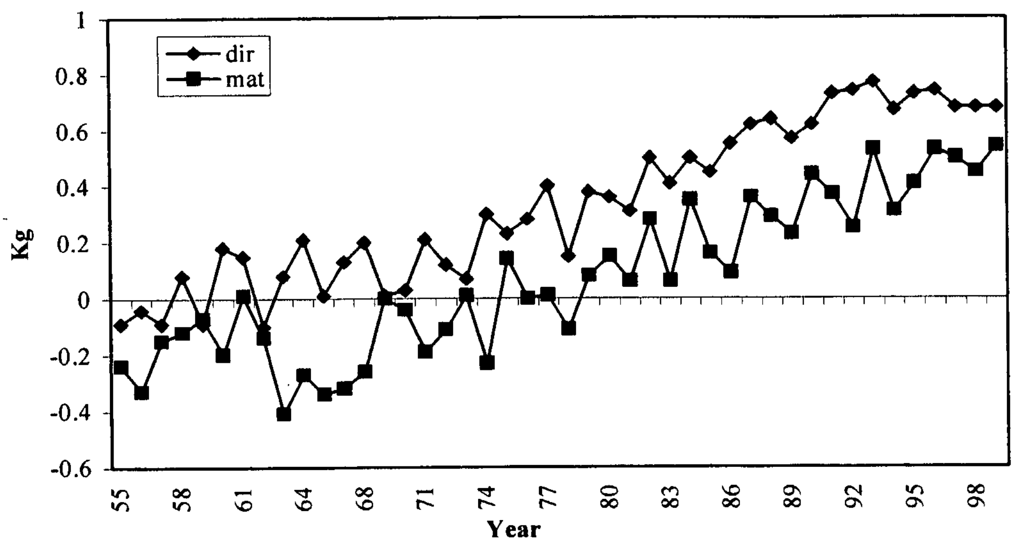

Figure 5.1a Direct (dir) and maternal (mat) genetic trends for weaning weight of Elsenburg SAMM sheep (1955-1999).

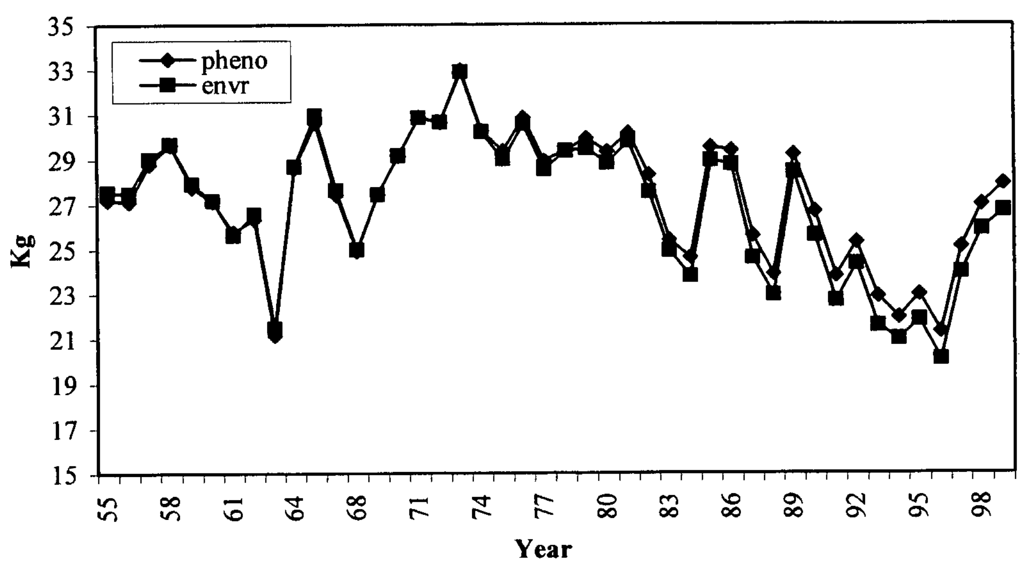

Figure 5.1b Phenotypic (pheno) and environmental (envr) trends for weaning weight of Elsenburg SAMM sheep (1955-1999).

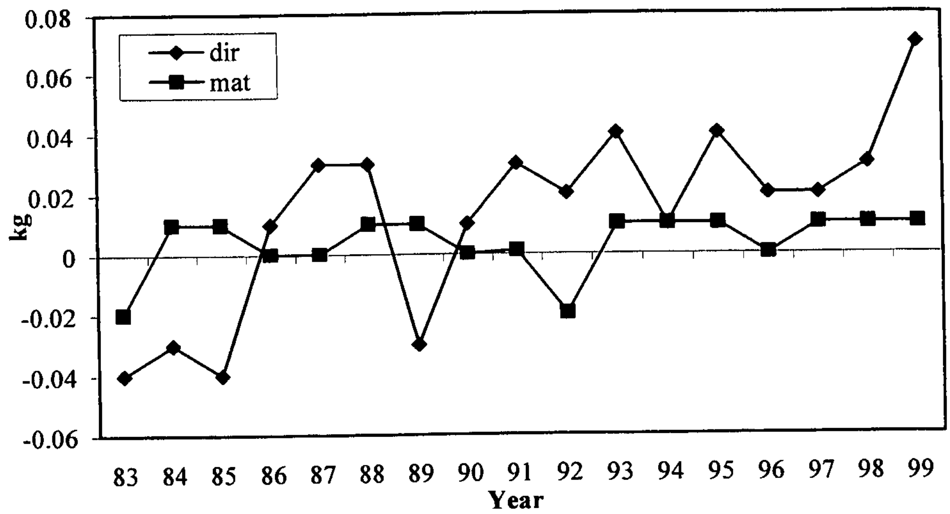

Figure 5.2a Direct (dir) and maternal (mat) genetic trends for clean fleece weight of Elsenburg SAMM sheep (1983-1999).

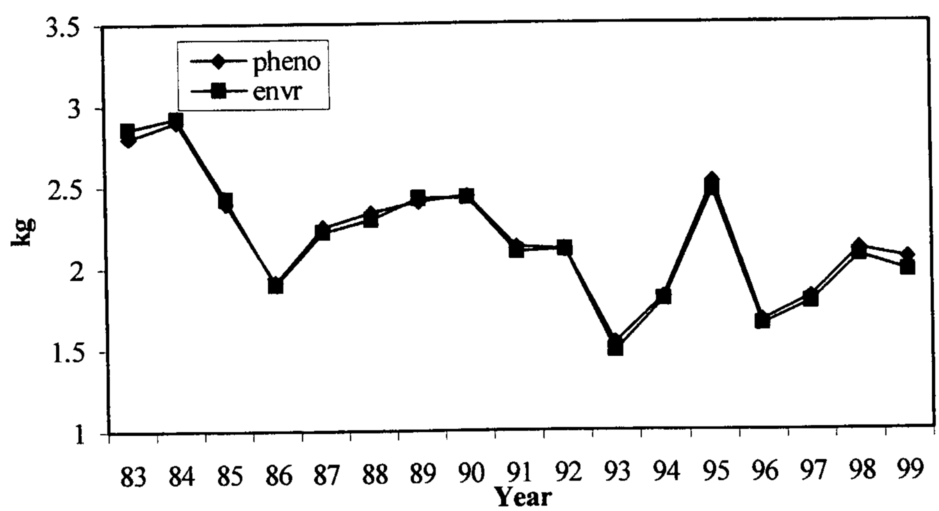

Figure 5.2b Phenotypic (pheno) and environmental (envr) trends for clean fleece weight of Elsenburg SAMM sheep (1983-1999).

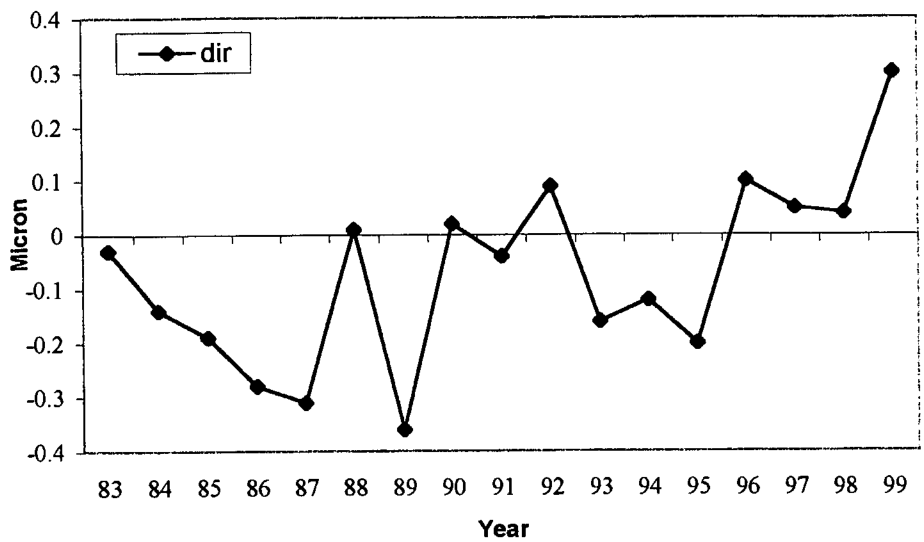

Figure 5.3a Direct (dir) genetic trend for mean fibre diameter of Elsenburg SAMM sheep (1983-1999).

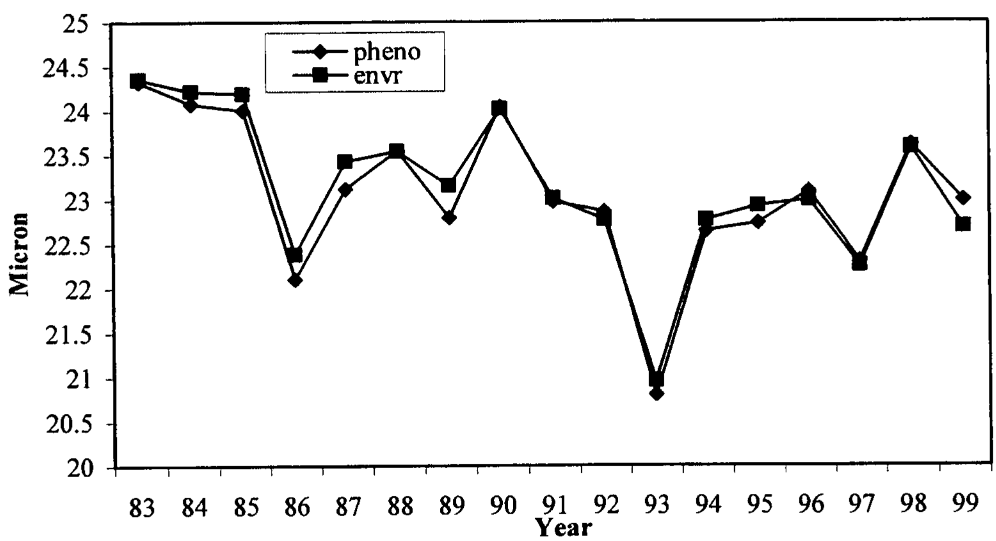

Figure 5.3b Phenotypic (pheno) and environmental (envr) trends for fibre diameter of Elsenburg SAMM sheep (1983-1999).

5.4 Conclusions

Genetic improvement in the Elsenburg SA Mutton Merino stud, although positive, was very slow. The use of advanced scientific procedures have shown that the selection policy followed did not maximize possible genetic gain. From the results it is obvious that there was very little direct selection for the traits studied and the small positive genetic trends can most probably be ascribed to correlated responses of selection for visually assessed traits. All genetic gains were, in addition, counteracted by the high levels of the negative environmental trends. Due to the need for finer wool the reduction in the environmental trend observed for the fiber diameter helped to counteract the slight increase in the genetic trend. There exist large fluctuations in the environmental trend. So provision of an adequate environment for the expression of the genetic potential need attention.

CHAPTER 6

GENERAL CONCLUSIONS

The validity of results of scientific analyses are dependent on the validity of the data and methods used to obtain them. With this in mind, some general conclusions are made from the present study.

The results firstly confirm the importance of non-genetic factors as sources of variation in body weights and fleece traits in the Elsenburg SA Mutton merino flock. Failure to include these factors in an operational model could have a negative influence on the selection progress due to the use of inaccurate genetic parameters and resulting breeding values in the selection program.

When fitting more sophisticated models, the assumptions made regarding the random part of the model could be even more important. This was illustrated in the change in log likelihoods by including or excluding maternal genetic and environmental effects in the model. If these effects are not included, genetic parameters could be inflated. Therefore, this study indicates that model specification regarding the fixed as well as the random part of the model is an important aspect in genetic parameter estimation and breeding values.

Heritability estimates for birth and weaning weight were found to be low. Based on these estimates it appears that it is difficult to improve these traits via selection. Heritability estimates for yearling weight was medium, while for wool traits, it was high. This implies that genetic improvement by selection for these traits will be easier to achieve.

The genetic relationship between yearling weight and wool traits were positive. However, the values are, with the exception of the correlation between greasy and clean fleece weight, low. This implies that correlated improvement of traits through selection for the other traits will not be high. In general there will be no antagonistic response, except for MFD, to selection for any one of the traits.

Monitoring of genetic changes is important in evaluating the success of selection programs. For most of the traits, the genetic trends show small genetic gains over the period of the study. However, due to negative environmental trends the genetic gain was not expressed in the improvement of the phenotypic performance. With the medium to high heritability estimates for yearling weight and wool traits, higher response would be possible, but the environmental conditions should allow for the expression of the genetic gain.

The results of this study generally show that selection for growth and wool traits has not been the primary selection objective in the 44 years covered by this study. The small positive genetic trends can most probably be ascribed to correlated responses of selection for visually assessed traits. All genetic gains were, in addition, counteracted by the high levels of the negative environmental trends.

This study provides evidence that genetic variability, which exists for all traits studied, can be utilized through selection to offer the Elsenburg SA Mutton merino stud an effective means for permanent genetic improvement of productivity. However, the environment provided should be adequate in order to result in an effective phenotypic improvement.

ABSTRACT

A total of 10717, 7795, and 2021 records of birth weight (BWT), weaning weight (WWT), and yearling weight (YRWT), respectively, and 1965 records of greasy (GFW) and clean fleece weight (CFW) and mean fibre diameter (MFD) were collected from the Elsenburg Mutton Merino sheep Stud and used in this study for estimation of genetic parameters and genetic and environmental trends. BWT and WWT were collected during the period 1955 to 1999 while YRWT and wool trait data were collected in the years 1983 to 1999.

Eight animal models formed from ignoring or inclusion of maternal genetic and environmental effects and direct-maternal covariance were used to identify the best model for estimation of genetic parameters from both univariate and bivariate analysis. Yearly means of phenotypic performance and breeding values were used to evaluate environmental and genetic trends.

Preliminary fixed model analysis showed that the fixed effects identified as having a significant ($P< 0.001$) effect on growth traits (BWT & WWT) were sex, birth status, age of dam and year. Year had a significant ($P< 0.0001$) effect on yearling weight and all fleece traits. Sex had a significant ($P< 0.0001$) effect on yearling weight, fleece weights and clean yield. Birth status had a significant ($P< 0.0001$) on yearling weight and fleece weights, and significant ($P< 0.001$) effect on mean fibre diameter. Age of dam had significant ($P< 0.001$) effect only on yearling weight. Some significant interactions were also found, but since they were very small, they were ignored.

Least-squares means were 4.24 ± 0.11 for BWT, 18.7 ± 1.73 For WWT, and 51.4 ± 0.16 for YRWT; 3.37 ± 0.18 for GFW, 2.19 ± 0.12 for CFW and 23.1 ± 0.04 (μm) for MFD.

Maternal genetic, permanent environmental, and common environmental effects were important for BWT, WWT, YRWT, and GFW while maternal genetic effects also had a significant contribution to CFW. The basic direct model was adequate for MFD.
Direct heritability estimates of 0.08, 0.04, 0.18, 0.37, 0.34 and 0.67 were obtained for BWT, WWT, YRWT, GFW, CFW and MFD respectively. Maternal heritability estimates of 0.20, 0.05, 0.05, 0.02 and 0.06 were obtained for BWT, WWT, YRWT, GFW and CFW, respectively.

The correlation between direct and maternal effects for growth traits were consistently negative, but positive for all fleece traits except for MFD.

Phenotypic correlations were generally positive and low to medium. Genetic correlations were also generally positive and low to medium. The genetic correlation between CFW and GFW was close to unity with a small standard error.

Breeding values were obtained as a by-product of the ASREML procedures. Environmental change, calculated as the difference between phenotypic and breeding values was negative for all traits. Genetic trends were small but positive. The high maternal trend for WWT reveal that the biggest genetic improvement was in the maternal genetic ability of ewes to produce heavier lambs.

OPSOMMING

Altesaam 10717 rekords vir geboortegewig (BWT), 7795 vir speengewig (WWT) en 2021 vir jaaroudgewig (YRWT) sowel as 1965 vir ruvaggewig (GFW), skoonvaggewig (CFW) en gemiddelde veseldikte (MFD) is verkry van die Elsenburgse Vleismerino skaapstoetery en gebruik in hierdie studie vir die beraming van genetiese parameters en genetiese- en omgewingstendense. BWT en WWT is ingesamel vanaf 1955 tot 1999 terwyl YRWT en die vageienskappe vanaf 1983 tot 1999 ingesamel is.

Agt dieremodelle is gepas wat gewissel het van met en sonder maternale genetiese en omgewings effekte en is gebruik om die beste model te kies vir die beraming van genetiese parameters vanaf beide enkel- en twee-eienskapanalise. Jaarlikse gemiddeldes van fenotipiese prestasie en teelwaardes is gebruik om onderskeidelik fenotipiese en genetiese tendense te beraam.

Voorlopige vastemodelanalise het getoon dat die vaste effekte met 'n betekenisvolle ($P<0.001$) effek op groeieienskappe (BWT en WWT) geslag, geboortestatus, moederouderdom en jaar van geboorte is. Jaar het 'n betekenisvolle ($P<0.0001$) effek op jaaroudgewig en al die vageienskappe gehad. Geslag het 'n betekenisvolle ($P<0.0001$) effek op YRWT en vaggewigte getoon. Geboortestaat het 'n betekenisvolle ($P<0.0001$) invloed op YRWT, vaggewigte en MFD gehad. Moederouderdom het 'n betekenisvolle ($P<0.001$) effek op YRWT getoon. Enkele betekenisvolle interaksies is ook verkry maar aangesien hulle baie klein was, is hulle geignoreer.

Kleinste kwadraad gemiddeldes (kg) was 4.24 ± 0.11 vir BWT, 18.7 ± 0.16 vir YRWT, 3.37 ± 0.18 vir GFW, 2.19 ± 0.12 vir CFW en 23.1 ± 0.04 (μ) vir MFD.

Maternaal-geneties-, permanente omgewing- en gemeenskaplike omgewingseffekte was belangrik vir BWT, WWT, YRWT en GFW terwyl maternale genetiese effekte ook betekenisvol tot CFW bygedra het. Die basiese model was voldoende vir MFD.

Direkte oorerflikheidsberamings van 0.08, 0.04, 0.18, 0.37, 0.34 en 0.67 is verkry vir onderskeidelik BWT, WWT, YRWT, GFW, CFW en MFD. Maternale oorerflikheidsberamings van 0.20, 0.05, 0.05, 0.02 en 0.06 is verkry vir BWT, WWT, YRWT, GWF en CFW onderskeidelik.

Die korrelasie tussen direkte en maternale effekte was deurgaans negatief maar positief vir alle vageienskappe behalwe MFD.

Fenotipiese korrelasies was oor die algemeen positief en laag tot medium behalwe vir 'n baie klein negatiewe korrelasie. Genetiese korrelasies was ook positief en laag tot medium. Die genetiese korrelasie tussen CFW en GFW was na aan een met 'n klein standaard fout.

Teelwaardes is verkry as byproduk van die ASREML prosedures. Omgewingsverandering, beraam as die verskil tussen fenotipiese- en teelwaardes, was negatief vir al die eienskappe. Genetiese tendense was laag maar positief. Die hoë maternale tendens vir WWT wys dat die grootste genetiese verbetering in die maternale vermoë van die ooi om swaarder lammers te produseer was.

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