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CORRELATIONS AMONG MOHAIR TRAITS, BODY WEIGHT AND REPRODUCTION IN SOUTH AFRICAN ANGORA GOATS

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INTRODUCTION

South African mohair producers contribute about 50% of the world's mohair production. During the 2018 season, the composition of the South African mohair clip comprised 19% Kid mohair, 23% Young goat mohair, 29% Fine adult mohair and 29% Strong adult mohair (Coetzee, 2019). As nearly 60% of the clip comes from adult animals, it is important that ewes should be able to maintain a high level of mohair production, in terms of fleece weight as well as fleece quality, throughout their flock life. Depending on the weaning percentage, reproduction rate contributes between 60% and 80% to the total annual income of an Angora ewe (Snyman, 2019). The contribution of reproduction to income is mainly through the mohair production of the kids at first and second shearing. Thus the higher the number of kids weaned in the flock, the higher the income generated from the more expensive kid mohair. Ewes producing heavy fleeces with fine fibre diameter and superior style and character will furthermore increase income generated from adult ewe mohair production. There are large differences in hair production, reproduction and income among ewes that had five or six kidding opportunities (Snyman, 2019). These differences could be exploited by placing selection emphasis on those traits that contribute most to yearly income and for which high levels of production can be maintained until an older age.

Selection of breeding sires is aimed at increasing gain in future generations, while selection of breeding dams is additionally aimed at increasing income generated from the current flock. As selection of young ewes takes place at 16 to 18 months of age, it is thus important to select animals with the highest lifetime fleece and reproduction potential. Sufficient phenotypic variance in reproduction (Snyman, 2010) and hair production (McGregor & Butler, 2014) exists among Angora ewes in a flock that could be exploited. Average kidding and weaning percentages reported for 12 South African Angora goat flocks that run under different management conditions ranged from 72.0 to 121.5% and 57.8 to 105.3% respectively (Snyman, 2010).

Selection criteria for Angora goats include body weight, fleece weight, fibre diameter and fleece quality traits, while not much emphasis is currently placed on reproduction (Snyman et al., 1996; Snyman & Olivier, 1999b; Ferguson & McGregor, 2004; Ferguson & McGregor, 2005). South African Angora goat stud breeders, however, appreciate the importance of reproduction and realise that the aim should be to have a genetically superior ewe flock in terms of reproductive potential. For the construction of the most effective breeding plan, it is imperative that accurate genetic parameters for the traits involved be available. Genetic parameters for various fleece traits, predominantly fleece weight and fibre diameter, have been reported for Australian (Gifford et al., 1991; Bolormaa et al., 2009), Argentinean (Taddeo et al., 1998), French (Allain & Roguet, 2003; Allain & Roguet, 2006), New Zealand (Nicoll et al., 1989) and South African (Snyman & Olivier, 1996; Snyman & Olivier, 1999a; Visser et al., 2009) Angora goats. Heritabilities for and genetic correlations among body weights have been estimated by Snyman & Olivier (1996), Snyman & Olivier (1999b) and Snyman (2012) for South African and by Bolormaa et al. (2009) for Australian Angora goats. Genetic parameters for reproductive traits in Angora goats are very scarce and have only been reported by Liu et al. (2002).

In this paper, genetic and phenotypic correlations between early and adult body weight, fleece traits and reproduction, as well as among the respective adult traits, have been estimated. These parameters will assist in the construction of breeding plans for the identification of animals at an early age with the highest lifetime fleece and reproduction potential, to facilitate maximum current flock gains.

MATERIALS AND METHODS

Animals and data collected

Data collected on the flocks of three South African Angora goat producers (Flocks A, B and C) from 2000 until 2015 were used in this study. More detail on the various traits that were recorded, as well as the abbreviations for the traits used in the text, are summarised in Table 1. During kidding, full pedigrees, birth date, sex and birth status of each kid were recorded.

Table 1. Description of the traits recorded

Trait and abbreviation of trait		Details of recording of the trait	Collected since [a]
Body weights			
Weaning weight (kg)	WW	Ram and ewe kids - Recorded weight, date and management groups at 100 to 120 days of age	2000
8-Month body weight (kg)	W8	Ram and ewe kids - Recorded weight, date and management groups at 8 months of age	2000
12-Month body weight (kg)	W12	Ewe kids and some ram and kapater kids in Flock A Ewe and ram kids in Flock B Ewe kids in Flock C Recorded weight, date and management groups at 12 months of age	2000

Trait and abbreviation of trait		Details of recording of the trait	Collected since [a]
16-Month body weight (kg)	W16	Ewe kids and some ram and kapater kids in Flock A Ewe and ram kids in Flock B Ewe kids in Flock C Recorded weight, date and management groups at 16 months of age	2000
Adult body weight (kg)	ABW	Before mating on all ewes	2005
Second shearing fleece traits			
Fleece weight (kg)	FW2	Ram and ewe kids Recorded fleece weight, management groups and current and previous shearing dates	2000
Fibre diameter (µm)	FD2	Determined with OFDA2000 on midrib fleece sample of all ram and ewe kids	
Coefficient of variation of fibre diameter (%)	CV2		
Standard deviation of fibre diameter (µm)	SD2		
Comfort factor (%)	CF2		
Standard deviation of fibre diameter along the length of the staple (µm)	SDA2		
Spinning fineness (µm)	SF2		
Staple length (mm)	SL2		
Number of fibres	NF2	Determined as described below table	
Third shearing fleece traits			
Fleece weight (kg)		Ram and ewe kids Recorded fleece weight, management groups and current and previous shearing dates	2000
Fibre diameter (µm)	FD3	Determined with OFDA2000 on midrib fleece sample of all ram and ewe kids	
Coefficient of variation of fibre diameter (%)	CV3		
Standard deviation of fibre diameter (µm)	SD3		
Comfort factor (%)	CF3		
Standard deviation of fibre diameter along the length of the staple (µm)	SDA3		
Spinning fineness (µm)	SF3		
Staple length (mm)	SL3		
Number of fibres	NF3	Determined as described below table	
Adult fleece traits (Ewes winter shearing)			
Fleece weight (kg)	AFW	Winter shearing of ewe flock Recorded fleece weight, management groups and current and previous shearing dates	2005
Fibre diameter (µm)	AFD	Determined with OFDA2000 on midrib fleece sample of all ewes	
Coefficient of variation of fibre diameter (%)	ACV		
Standard deviation of fibre diameter (µm)	ASD		
Comfort factor (%)	ACF		

Trait and abbreviation of trait		Details of recording of the trait	Collected since [a]
Standard deviation of fibre diameter along the length of the staple (µm)	ASDA		
Spinning fineness (µm)	ASF		
Staple length (mm)	ASL		
Number of fibres	ANF	Determined as described below table	
Reproduction			
Ewe mated or not		Recorded annually during mating and kidding seasons	2000
Ewe kidded or not			
Number of kids born per ewe			
Number of kids weaned per ewe			
The following were calculated from the above recorded reproductive data:			
Total weight of kid weaned / year (kg)	TWW	Sum of sex-corrected weaning weights of all kids weaned by a ewe for a specific kidding season	2000
Number of kids born / year	NKB	Number of kids born to a ewe in a specific kidding season	
Number of kids weaned / year	NKW	Number of kids weaned by a ewe in a specific kidding season	
Total weight of kid weaned at first parity (kg)	TWW1	Sum of sex-corrected weaning weights of all kids weaned by a ewe during her first kidding season	
Number of kids born at first parity	NKB1	Number of kids born to a ewe during her first kidding season	
Number of kids weaned at first parity	NKW1	Number of kids weaned by a ewe during her first kidding season	

[a] Data on Flock A and B collected until 2015; Data on Flock C collected until 2010

The number of fibres per animal (NF) at each shearing was calculated from the respective fleece weight, fibre diameter and staple length, using the following formula:

$$NF = \frac{FW}{S_g \pi r^2 l}$$

where: NF = the number of fibres per animal,
FW = fleece weight (g),
S_g = the specific gravity of mohair (1.31 g/cm^3),
r = the radius of the fibre (cm),
l = the length of the fibre (cm).

The management practices followed in the three flocks at various stages of the reproductive cycle of the ewes and growth cycle of the kids were discussed by Snyman (2007) and Snyman (2010). Flock A corresponds to Flock 5, while Flock B and Flock C respectively correspond to Flock 7 and Flock 12 in Snyman (2007) and Snyman (2010).

Estimation of genetic and phenotypic correlations

The same pedigree file was used for the analyses of all the traits. The pedigree structure of the dataset is summarised in Table 2.

Table 2. Pedigree structure of the dataset

Item	**Number of animals**
No. of animals in pedigree file	27850
No. of animals with own records	Table 3 in Snyman (2019)
No. of sires	602
No. of sires of sire	142
No. of dams	7342
No. of dams of dam	2699

For the estimation of correlations of early body weight and fleece traits and maiden reproductive performance with adult body weight, fleece traits and reproduction, bivariate animal models were fitted (ASReml program; Gilmour et al., 2014). In each case, a repeatability model was fitted for the trait recorded on the adult ewe. Direct additive genetic effects and animal permanent environmental effects (where applicable) were included. All available data on the specific traits were included in the bivariate analyses.

For the estimation of correlations among the reproductive traits, adult fleece traits and adult body weight, bivariate models including direct additive genetic effects and animal permanent environmental effects were fitted (ASReml program; Gilmour et al., 2014). A repeatability model, including all available data recorded for the ewes on the specific trait, was fitted for each trait included in the bivariate analysis.

Fixed effects for flock, year of recording, shearing group, dam age group (8 years or younger or older than 8 years) and age at recording (in months) were fitted for each early fleece trait. For the early body weights, fixed effects for flock, year of recording, rearing status (birth status for birth weight), rearing group, age of dam and age at recording (in days) were fitted.

The following fixed effects were fitted for the adult traits: For the reproduction traits, fixed effects for flock, year of recording, mating group, year of birth of the ewe and age at recording (in months) were fitted. For body weight, fixed effects for flock, year of recording and age at recording (in months) were fitted. For the fleece traits, fixed effects for flock, year of recording, shearing group and age at recording (in months) were fitted.

RESULTS AND DISCUSSION

A full description of the dataset in terms of the number of records, mean, minimum, maximum and coefficients of variation of the various traits recorded or calculated can be found in Snyman (2019). Heritabilities for all these traits can be found in Snyman (2018). Medium heritabilities were obtained for body weight and fleece weight and a high heritability was estimated for fibre diameter. This implies that if any of these traits are included in the selection objective and selection is based on own performance records for the specific trait, genetic progress in the trait will result. With the exception of SDA and SL, which had low heritabilities, medium heritabilities were estimated for the other fibre diameter profile traits.

Although low heritabilities were estimated for maiden ewe reproductive performance at the first parity, the high coefficients of variation for TWW1, NKB1 and NKW1 imply scope for selection that could be exploited to genetically improve reproductive performance of the adult ewe flock by culling unproductive maiden ewes. However, when this practice is implemented, care should be taken that maiden ewes reach an acceptable body weight at first mating (Snyman, 2010). The low heritability estimates obtained for the reproductive traits in this study are typical for these parameters in various breeds and species.

Genetic correlations of early body weight, fleece traits and maiden reproductive performance with adult body weight and fleece traits are presented in Table 3. Selection for early fleece weight will lead to a favourable genetic increase in adult body weight, fleece weight and staple length, but an unfavourable increase in adult fibre diameter. Furthermore, there will also be an unfavourable effect on the fibre diameter traits ASD, ACF, ASDA and ASF. TWW should increase when selection is based on early fleece weight.

Genetic correlations of early fibre diameter with adult traits were the opposite of those of early fleece weight. Selection for early fibre diameter will lead to a favourable genetic increase in adult fibre diameter, ASD, ACF, ASDA and ASF. However, an unfavourable decrease in adult body weight, fleece weight, staple length and TWW could be expected when selection is based on early fibre diameter. ACV will also increase unfavourably.

Selection for the early fibre diameter profile traits (CV, SD, CF, SDA and SF) generally will have no effect on adult body weight, fleece weight, staple length or reproduction. All these traits are favourably correlated with adult fibre diameter, and where significant, also favourably correlated with the adult fibre diameter profile traits. The exception is the unfavourable correlation between early CV and adult fibre diameter and ACF. The only significant response in adult traits when selection is based on early staple length will be in adult staple length. Number of fibres per animal at an early age was favourably correlated with adult fleece weight and fibre diameter, ACF, ASDA and ASF, but unfavourably correlated with ACV.

Table 3. Genetic correlations (± s.e.) of early fleece traits, body weight and maiden reproductive performance with adult performance traits

Trait	**ABW**	**AFW**	**AFD**	**ACV**	**ASD**	**ACF**	**ASDA**	**ASF**	**ASL**	**TWW**	**NLB**	**NLW**
FW2	0.35 ± 0.07*	0.54 ± 0.04*	0.62 ± 0.05*	-0.09 ± 0.09	0.17 ± 0.08*	-0.44 ± 0.08*	0.27 ± 0.12*	0.35 ± 0.08*	0.32 ± 0.12*	0.41 ± 0.10*	0.00 ± 0.11	0.03 ± 0.12
FW3	0.37 ± 0.05*	0.83 ± 0.03*	0.78 ± 0.03*	-0.20 ± 0.08*	0.57 ± 0.07*	-0.82 ± 0.05*	0.85 ± 0.07*	0.83 ± 0.04*	0.84 ± 0.07*	0.35 ± 0.08*	0.11 ± 0.08	0.21 ± 0.09*
FD2	0.32 ± 0.05*	0.16 ± 0.03*	0.89 ± 0.01*	-0.25 ± 0.06*	0.33 ± 0.04*	-0.68 ± 0.04*	0.44 ± 0.06*	0.66 ± 0.04*	-0.04 ± 0.07	0.57 ± 0.07*	0.17 ± 0.06*	0.21 ± 0.07*
FD3	0.32 ± 0.05*	0.47 ± 0.06*	0.94 ± 0.04*	-0.40 ± 0.05*	0.64 ± 0.03*	-0.93 ± 0.01*	0.77 ± 0.06*	0.95 ± 0.01*	0.36 ± 0.07*	0.57 ± 0.07*	0.17 ± 0.06*	0.21 ± 0.07*
CV2	0.01 ± 0.06	0.18 ± 0.04*	-0.64 ± 0.03*	0.73 ± 0.05*	0.36 ± 0.04*	0.43 ± 0.05*	0.18 ± 0.06*	-0.11 ± 0.05*	-0.04 ± 0.08	-0.05 ± 0.10	-0.05 ± 0.07	0.07 ± 0.09
CV3	0.11 ± 0.06	NC	-0.59 ± 0.04*	0.89 ± 0.03*	0.47 ± 0.04*	0.54 ± 0.05*	0.29 ± 0.06*	-0.14 ± 0.05*	-0.06 ± 0.08	0.11 ± 0.10	0.12 ± 0.07	0.18 ± 0.09
SD2	0.25 ± 0.06*	0.20 ± 0.04*	0.74 ± 0.03*	0.46 ± 0.06*	0.56 ± 0.05*	-0.13 ± 0.06*	0.41 ± 0.07*	0.40 ± 0.05*	-0.02 ± 0.08	0.34 ± 0.10*	-0.01 ± 0.09	0.12 ± 0.10
SD3	0.27 ± 0.06*	0.10 ± 0.04	0.58 ± 0.04*	0.71 ± 0.05*	0.75 ± 0.04*	-0.13 ± 0.06*	0.54 ± 0.07*	0.48 ± 0.05*	0.01 ± 0.07	0.35 ± 0.10*	0.21 ± 0.09*	0.28 ± 0.10*
CF2	-0.35 ± 0.04*	-0.03 ± 0.04	-0.97 ± 0.01*	0.11 ± 0.05*	-0.41 ± 0.04*	0.63 ± 0.04*	-0.47 ± 0.07*	-0.65 ± 0.03*	0.08 ± 0.07	-0.67 ± 0.09*	-0.15 ± 0.08	-0.24 ± 0.10*
CF3	-0.22 ± 0.05*	NC	-0.99 ± 0.01*	NC	NC	NC	NC	-0.78 ± 0.02*	-0.09 ± 0.06	-0.34 ± 0.08*	NC	NC
SDA2	0.16 ± 0.09	0.20 ± 0.04*	0.77 ± 0.04*	-0.26 ± 0.09*	0.12 ± 0.09	-0.47 ± 0.08*	0.40 ± 0.12*	0.40 ± 0.08*	0.11 ± 0.11	0.24 ± 0.14	-0.13 ± 0.14	-0.06 ± 0.17
SDA3	0.09 ± 0.08	0.16 ± 0.05*	0.66 ± 0.06*	-0.02 ± 0.09	0.32 ± 0.08*	-0.37 ± 0.08*	0.55 ± 0.11*	0.45 ± 0.07*	0.29 ± 0.10*	0.31 ± 0.13*	0.24 ± 0.13	0.28 ± 0.15
SF2	0.37 ± 0.05*	0.12 ± 0.04*	0.98 ± 0.01*	-0.03 ± 0.06	0.44 ± 0.04*	-0.57 ± 0.04*	0.47 ± 0.07*	0.63 ± 0.04*	-0.07 ± 0.07	0.60 ± 0.09*	0.10 ± 0.08	0.21 ± 0.09*
SF3	0.28 ± 0.05*	NC	NC	-0.02 ± 0.06	0.59 ± 0.04*	-0.70 ± 0.04*	0.52 ± 0.07*	0.78 ± 0.03*	0.03 ± 0.07	0.37 ± 0.09*	0.15 ± 0.08	0.20 ± 0.09*
SL2	0.00 ± 0.04	0.09 ± 0.03	0.14 ± 0.03*	-0.05 ± 0.04	0.01 ± 0.04	-0.08 ± 0.04	0.01 ± 0.05	0.05 ± 0.03	0.24 ± 0.08*	0.05 ± 0.07	-0.01 ± 0.07	NC
SL3	-0.05 ± 0.04	0.05 ± 0.04	0.25 ± 0.04*	-0.20 ± 0.05*	0.01 ± 0.05	-0.31 ± 0.06*	0.16 ± 0.06	0.18 ± 0.04*	0.71 ± 0.10*	-0.12 ± 0.10	0.07 ± 0.08	-0.08 ± 0.09

Trait	ABW	AFW	AFD	ACV	ASD	ACF	ASDA	ASF	ASL	TWW	NLB	NLW
NF2	0.05 ± 0.08	0.41 ± 0.04*	-0.61 ± 0.04*	0.28 ± 0.07*	-0.12 ± 0.06	0.45 ± 0.07*	-0.33 ± 0.08*	-0.35 ± 0.05*	-0.01 ± 0.10	-0.25 ± 0.12	-0.01 ± 0.09	-0.19 ± 0.10
NF3	0.14 ± 0.08	0.60 ± 0.07*	-0.76 ± 0.04*	0.29 ± 0.07*	-0.07 ± 0.05	0.47 ± 0.07*	-0.16 ± 0.07*	-0.32 ± 0.05*	-0.08 ± 0.10	-0.09 ± 0.12	0.38 ± 0.60	0.50 ± 0.81
WW	0.86 ± 0.03*	0.18 ± 0.03*	0.37 ± 0.04*	0.09 ± 0.06	0.04 ± 0.04	0.03 ± 0.06	0.07 ± 0.06	0.02 ± 0.05	-0.05 ± 0.07	0.90 ± 0.04*	0.48 ± 0.07*	0.54 ± 0.08*
W8	0.84 ± 0.05*	0.14 ± 0.04*	0.28 ± 0.05*	-0.03 ± 0.06	-0.02 ± 0.05	0.03 ± 0.07	0.18 ± 0.07*	-0.04 ± 0.05	-0.06 ± 0.09	0.92 ± 0.06*	0.51 ± 0.07*	0.57 ± 0.08*
W12	0.96 ± 0.02*	0.06 ± 0.04	0.61 ± 0.04*	-0.03 ± 0.07	0.00 ± 0.05	-0.07 ± 0.07	0.03 ± 0.07	0.03 ± 0.05	-0.28 ± 0.09*	0.96 ± 0.05*	0.65 ± 0.07*	0.72 ± 0.08*
W16	0.97 ± 0.01*	0.17 ± 0.04*	0.56 ± 0.04*	0.15 ± 0.07*	0.16 ± 0.04*	-0.02 ± 0.06	0.07 ± 0.06	0.10 ± 0.05	-0.01 ± 0.08	0.99 ± 0.12*	0.72 ± 0.07*	0.78 ± 0.07*
TWW1	0.99 ± 0.05*	0.34 ± 0.54	-0.25 ± 0.68	0.14 ± 0.04*	0.08 ± 0.04	0.24 ± 0.10*	0.04 ± 0.05	-0.02 ± 0.04	-0.05 ± 0.12	0.99 ± 0.17*	0.85 ± 0.30*	0.76 ± 0.40
NKB1	NC	0.66 ± 3.09	-0.47 ± 1.10	0.24 ± 0.09*	0.12 ± 0.08	0.19 ± 0.09*	0.17 ± 0.11	-0.06 ± 0.08	0.13 ± 0.10	0.83 ± 0.31*	0.92 ± 0.21*	0.91 ± 0.29*
NKW1	NC	0.39 ± 0.79	-0.01 ± 0.49	0.22 ± 0.09*	0.06 ± 0.08	0.22 ± 0.09*	0.21 ± 0.11	-0.12 ± 0.08	0.07 ± 0.11	0.74 ± 0.25*	0.94 ± 0.11*	0.77 ± 0.27*

* Significant correlation; NC = Models did not converge.

Selection for early body weight will have a favourable effect on adult body weight and reproduction, and an unfavourable effect on adult fibre diameter and should not influence adult fleece weight. Selection on maiden ewe reproductive performance will lead to an increased adult reproductive performance. Except for the favourable correlation between TWW1 and adult body weight, genetic correlations estimated between maiden reproductive performance and adult body weight, fleece weight and fibre diameter were unreliable due to very high standard errors.

Genetic and phenotypic correlations estimated between the reproductive traits and adult fleece traits and body weight are presented in Tables 4 and 5 respectively.

Table 4. Genetic correlations (± s.e.) of body weight and adult fleece traits with adult body weight, fleece weight, fibre diameter and reproductive traits (TWW, NKB, NKW)

Adult traits	ABW	AFW	AFD	TWW	NKB	NKW
Body weight	-	0.05 ± 0.04	-0.03 ± 0.04	0.34 ± 0.08*	0.12 ± 0.08	0.01 ± 0.08
Fleece weight	-	-	0.76 ± 0.02*	-0.41 ± 0.09*	-0.22 ± 0.07*	-0.32 ± 0.08*
Fibre diameter	-	-	-	-0.47 ± 0.09*	-0.31 ± 0.08*	-0.46 ± 0.10*
Coefficient of variation of fibre diameter	0.22 ± 0.05*	-0.26 ± 0.04*	-0.55 ± 0.03*	0.31 ± 0.10*	0.23 ± 0.09*	0.28 ± 0.10*
Standard deviation of fibre diameter	0.15 ± 0.04*	0.63 ± 0.04*	0.75 ± 0.02*	-0.12 ± 0.09	-0.05 ± 0.08	-0.10 ± 0.09
Comfort factor	0.02 ± 0.04	-0.83 ± 0.01*	0.99 ± 0.01*	0.52 ± 0.10*	0.32 ± 0.09*	0.47 ± 0.10*
Standard deviation of fibre diameter along length of staple	-0.07 ± 0.06	0.55 ± 0.05*	0.63 ± 0.01*	-0.08 ± 0.11	0.07 ± 0.12	0.01 ± 0.12
Spinning fineness	0.03 ± 0.04	0.81 ± 0.02*	0.98 ± 0.00*	-0.43 ± 0.09*	-0.27 ± 0.09*	-0.41 ± 0.09*
Staple length	-0.14 ± 0.05	0.17 ± 0.06*	0.31 ± 0.05*	-0.22 ± 0.11	-0.16 ± 0.11	-0.15 ± 0.11
Number of fibres	0.06 ± 0.04	0.39 ± 0.04*	-0.62 ± 0.03*	-0.01 ± 0.08	-0.02 ± 0.08	0.07 ± 0.08

* Significant correlation.

Table 5. Phenotypic correlations (± s.e.) of body weight and adult fleece traits with adult body weight, fleece weight, fibre diameter and reproductive traits (TWW, NKB, NKW)

Adult traits	**ABW**	**AFW**	**AFD**	**TWW**	**NKB**	**NKW**
Body weight	-	0.07 ± 0.02	0.12 ± 0.02	0.19 ± 0.02*	0.17 ± 0.01*	0.13 ± 0.01
Fleece weight	-	-	0.59 ± 0.01*	-0.06 ± 0.01	-0.03 ± 0.01	-0.05 ± 0.01
Fibre diameter	-	-	-	-0.03 ± 0.01	0.01 ± 0.01	-0.02 ± 0.01
Coefficient of variation of fibre diameter	0.08 ± 0.02	-0.15 ± 0.01	-0.27 ± 0.01*	0.05 ± 0.01	0.03 ± 0.01	0.04 ± 0.01
Standard deviation of fibre diameter	0.14 ± 0.02	0.26 ± 0.01*	0.45 ± 0.01*	0.03 ± 0.01	0.03 ± 0.01	0.02 ± 0.01
Comfort factor	-0.08 ± 0.02	-0.62 ± 0.01	-0.95 ± 0.00*	0.04 ± 0.01	0.01 ± 0.01	0.03 ± 0.01
Standard deviation of fibre diameter along length of staple	-0.01 ± 0.01	0.15 ± 0.09	0.19 ± 0.01*	0.02 ± 0.01	0.01 ± 0.01	0.01 ± 0.01
Spinning fineness	0.13 ± 0.02	0.57 ± 0.01*	0.94 ± 0.00*	-0.02 ± 0.01	0.01 ± 0.01	-0.02 ± 0.01
Staple length	-0.07 ± 0.01	0.02 ± 0.01	0.04 ± 0.01	-0.02 ± 0.01	0.01 ± 0.01	0.01 ± 0.01
Number of fibres	-0.01 ± 0.01	0.26 ± 0.01*	-0.33 ± 0.01*	-0.04 ± 0.01	-0.03 ± 0.01	-0.02 ± 0.01

* Significant correlation.

As far as the genetic correlations among the adult traits are concerned, adult fleece weight was unfavourably correlated with reproduction, fibre diameter and the fibre diameter profile traits. However, there was a favourable correlation between adult fleece weight and number of fibres in the fleece, staple length and CV. Adult fibre diameter was unfavourably correlated with fleece weight, CV, staple length and number of fibres, but favourably correlated with reproduction, SD, CF, SDA and SF. There were favourable significant genetic correlations of reproduction with adult body weight, fibre diameter, spinning fineness and comfort factor. Significant unfavourable genetic correlations of reproduction with fleece weight and CV of fibre diameter were estimated. The most important genetic correlation in terms of current flock income is the unfavourable genetic correlations of reproduction with adult fleece weight. All phenotypic correlations of reproduction with the other adult traits, except for body weight, were negligible. The contradiction between the sign of the genetic correlation of early and adult fleece weight with lifetime reproduction could possibly be explained through the fact that fleece production in Angora ewes decreases with age after peaking at three years of age (Snyman, 2018).

When comparing early production and reproduction traits of Angora ewes allocated to the Top 100 Income and Bottom 100 Income categories on the basis of yearly income (Snyman, 2019), significant differences in third shearing fleece weight and fibre diameter, early body weight and maiden reproductive performance were evident. Ewes in the Top 100 category had higher early body and fleece weights, fibre diameter and reproduction than ewes in the Bottom 100 category. These results confirmed the genetic correlations obtained with this study.

CONCLUSIONS

Reproduction contributes the most to total yearly income and fortunately ewes are able to maintain high reproductive levels up to the age of 7 years. Unfortunately, the reproductive traits have the lowest heritability of all the economically important traits. Body weight indirectly contributes to reproduction through favourable genetic correlations with reproduction. Selection of young ewes should therefore be focused on early body weight, number of kids produced and weight of kids weaned at the first parity.

The negative relationship between reproduction and fleece production in the adult ewes emphasises the fact that positive selection pressure on early fleece weight should not be done at the cost of reproduction. Only young ewes with unacceptably low fleece weights should be culled, while too much selection pressure on early fibre diameter in the young ewes should also be avoided. Selection for fleece production and fleece traits should rather be addressed through ram selection.

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REFERENCES

Allain, D. & Roguet, J.M., 2003. Genetic and non-genetic factors influencing mohair production traits within the national selection scheme of Angora goats in France. Livest. Prod. Sci. 82, 129-37.

Allain, D. & Roguet, J.M., 2006. Genetic and non-genetic variability of OFDA-medullated fibre contents and other fleece traits in the French Angora goats. Small Rumin. Res. 65, 217-222.

Bolormaa, S., Olayemi, M., Van der Werf, J.H.J., Baillie, N., Le Jambre, F., Ruvinsky, A. & Walkden-Brown, S.W., 2009. Estimates of genetic and phenotypic parameters for production, haematological and gastrointestinal nematode-associated traits in Australian Angora goats. Anim. Prod. Sci. 50(1), 25-36.

Coetzee, M., 2019. 2018 Mohair Report. Mohair. 60(2018/2019), 8-9.

Ferguson, M.B. & McGregor, B.A., 2004. An evaluation of Angora sires through progeny testing - a progress report. S. Afr. J. Anim. Sci. 34(5), 7-9.

Ferguson, M.B. & McGregor, B.A., 2005. Selecting High Performing Angoras. A report for the Rural Industries Research and Development Corporation. RIRDC Publication No 05/141. RIRDC Project No DAV-191A.

Gifford, D.R., Ponzoni, R.W., Lampe, R.J. & Burr, J., 1991. Phenotypic and genetic parameters of fleece traits and live weight in South Australian Angora goats. Small Rumin. Res. 4, 293-302.

Gilmour, A.R., Gogel, B.J., Cullis, B.R., Welham, S.J. & Thompson, R., 2014. ASReml User Guide Release 4.1 Structural Specification, VSN International Ltd, Hemel Hempstead, HP1 1ES, UK. www.vsni.co.uk.

Liu, W., Zhang, Y., Zhou, Z. & Guo, C., 2002. Estimation of genetic parameters for reproductive traits in Angora goats. 7th Wrld. Congr. Gen. Appl. Livest. Prod. August 19-23, 2002, Montpellier, France.

McGregor, B.A. & Butler, K.L., 2014. The value of visual fleece assessment in addition to objective measurements in identifying Angora goats of greater clean mohair production. Small Rumin. Res. 120, 51-63.

Nicoll, G.B., Bigham, M.L. & Alderton, M.J., 1989. Estimates of environmental effects and genetic parameters for liveweights and fleece traits of Angora goats. Proc. N.Z. Soc. Anim. Prod. 49, 183-189.

Snyman, M.A., 2007. Body weight and growth rate of South African Angora goat kids under different pre- and post-weaning management systems. S. Afr. J Anim. Sci. 37(2), 132-141.

Snyman, M.A., 2010. Influence of body weight, age and management system on reproduction of South African Angora goat does. S. Afr. J. Anim. Sci. 40(1), 41-53.

Snyman, M.A., 2012. Genetic analysis of body weight in South African Angora kids and young goats. S. Afr. J. Anim. Sci. 42(2), 146-155.

Snyman, M.A., 2018. Final Report AP2/18. Longevity of production in South African Angora goat ewes. Animal Production Unit, Grootfontein Agricultural Development Institute.

Snyman, M.A., 2019. Hair production, reproduction and income of Angora goat ewes that had five or six kidding opportunities in the flock. Grootfontein Agric 19(1), 1-19.

Snyman, M.A. & Olivier, J.J., 1996. Genetic parameters for body weight, fleece weight and fibre diameter in South African Angora goats. Livest. Prod. Sci., 47(1), 1-6.

Snyman, M.A. & Olivier, J.J., 1999a. Repeatability of objective and subjective fleece traits and body weight in South African Angora goats. Small Rumin. Res. 34(2), 103-109.

Snyman, M.A. & Olivier, J.J., 1999b. Performance testing - the road to future Angora goat breeding. Angora goat Mohair J. 41(1), 47-54.

Snyman, M.A., Olivier, J.J. & Wentzel, D., 1996. Breeding plans for South African Angora goats. Angora goat Mohair J. 38(1), 23-31.

Taddeo, H.R., Allain, D., Mueller, J., Rochambeau, H. & Manfredi, E., 1998. Genetic parameter estimates of production traits of Angora goats in Argentina. Small Rumin. Res. 28, 217-23.

Visser, C., Snyman, M.A., Van Marle-Köster, E. & Bovenhuis, H., 2009. Genetic parameters for physical and quality traits of mohair in South African Angora goats. Small Rumin. Res. 87, 27-32.