The relationships between faecal worm egg count and subjectively assessed wool and conformation traits in the Tygerhoek Merino flock

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Abstract

Subjectively assessed wool and conformation traits form part of the selection objective in wool sheep enterprises. The present study investigated the genetic, phenotypic and environmental correlations for nematode resistance (using faecal worm egg count (FEC)) with subjectively assessed wool and conformation traits. The Merino sheep flock (consisting of four lines) maintained on Tygerhoek Research Farm was used. Fixed effects of selection line, birth type, sex, age of dam in years, year of birth, and sex*birth year interaction had a significant effect on all subjective traits. At genetic level, log transformed FEC was significantly related to wool oil only at 0.18 ± 0.09, staple formation at 0.29 ± 0.10, and topline at −0.33 ± 0.11. These correlations suggested that sheep with high FEC are likely to have excessive wool oil, thicker and bulkier staples, and lower scores for topline. Selection for resistance to and resilience against nematodes in Merino sheep thus will not result in marked unfavourable correlated responses in the vast majority of these subjective wool and body conformation traits.

Keywords: Linearly assessed traits, faecal worm egg count, conformation, correlations
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Introduction

Merino sheep improvement programmes use objective measurements and subjective assessment for traits that are included in the selection objectives. The use of subjectively assessed traits for selecting breeding sires and dams is still prevalent in South African Merino sheep (Olivier *et al*., 2006) and in the Dorper, the dominant meat sheep breed in South Africa (Olivier & Cloete, 2006; Zirishi *et al*., 2012). In some instances, animals are culled based on these traits without considering unfavourable correlated response in other economically important traits (Olivier & Cloete 2006; Olivier *et al*., 2006). The reluctance of farmers to use objective measurements for Merino sheep selection criteria led to the development of a linear-type scoring method (Olivier *et al*., 1987). Genetic studies of visually assessed traits and their relationships to traits of economic importance followed in Merinos and Afrinos (Snyman & Olivier, 2002; Matebesi *et al*., 2009a; b) and more recently in Dorpers (Zishiri *et al*., 2012).

Research has emphasized the need to include health traits (Miglior, 2004) and indicators of reproduction (Olivier, 1999) in livestock genetic studies to justify their inclusion in breeding programmes. This is because selection for production only may pose potential health risks while compromising reproduction performance (Haile-Mariam *et al.*, 2004). In an attempt to include health traits in genetic studies, research globally has included the genetics of nematode resistance and resilience in sheep flocks, using faecal worm egg count (FEC) as an indicator trait and their relationships with objectively measured wool traits and liveweight (Greeff *et al*., 1995; Morris *et al*., 1996; 1997; Cloete *et al*., 2000; Khusro *et al*., 2004; Yadav *et al*., 2006; Cloete *et al*., 2007; Snyman, 2007). Relationships between FEC and subjectively assessed wool and conformation traits are limited to total fold score (TOT) in South African Merino sheep (Cloete *et al*., 2000; 2007). Studies of the genetic correlation between FEC and other subjectively assessed wool and conformation traits could not be found elsewhere. It is therefore important to investigate the relationships between subjectively assessed traits and FEC because sheep farmers still use subjective assessment to

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select breeding rams and ewes without knowledge of any correlated response to selection for FEC. The present study involving the relationships of FEC with subjectively assessed wool and conformation traits will form the foundation for future investigations.

Therefore, the objectives of the current study were to investigate the genetic, phenotypic and environmental correlations of FEC with subjectively assessed wool and conformation traits in the Tygerhoek Merino resource flock.

Material and Methods

The Merino flock that consisted of four lines maintained on the Tygerhoek experimental farm was used as experimental animals in the current study. Further description of the lines and selection practices are provided in a companion paper (Matebesi-Ranthimo *et al*., 2014). The database consisted of 5891 FEC and between 6789 (topline) and 7167 (three wool traits) subjectively assessed wool and conformation performance records. Description of the FEC data and information regarding the recording, transformation and derived parameters for FEC can be found in the paper by Matebesi-Ranthimo *et al*. (2014).

Table 1 Linear scale used to assess the subjective fleece and conformation traits in Tygerhoek Merino sheep (adapted from Olivier *et al*., 1987)

Trait	Scale of assessment		
	1	**25**	**50**
Subjective wool			
Face cover score (FCS)	Hard	Average	Soft
Pigmentation (PIGM)	Excessive	Average	None
Woolly face score (WFS)	Woolly faced	Ideal	Open faced
Quality (QUAL)	Poor	Average	Ideal
Regularity of crimp (ROC)	Poor–huge variation	Average	Ideal–no variation
Colour (COL)	Yellow	Average	White
Oil (OIL)	None	Ideal	Excessive
Staple formation (STAPL)	Ropy	Average	Thick, blocky
Belly and points (BANDP)	Watery, yellow	Average	Thick, white
Subjective conformation			
Head general (GEN)	Weak small	Average	Strong
Hocks (HOCKS)	Narrow	Average	Wide
Front quarters (FQ)	Narrow	Average	Wide
Pastern score (PS)	Weak	Average	Strong
Top line (TOPL)	Poor-Hollow	Average	Ideal-straight
Total fold score (TOT)	Plain (score=1)	-	Most wrinkly (score=17)

The following partitioning applied to most of traits: 1 - 10 = poor; 11 - 20 = below average; 21 - 30 = average; 31 - 40 = above average and 41 - 50 = excellent. The exceptions were woolly face score and oil, which had an intermediate optimum.

Subjectively assessed traits were scored according to a linear scale (Table1) ranging from 1 to 50 (Olivier *et al*., 1987) at 14 - 16 months of age as described by Matebesi *et al*. (2009a). At least three experienced judges were used to allocate the scores for individual animals. The scores given by the judges were averaged to provide a final score for that trait in each animal. TOT was scored according to photographic standards for wrinkles on the neck, body and breech.

The data used for the analysis of subjectively assessed wool and conformation traits were edited as described by Matebesi-Ranthimo *et al*. (2014). Similar procedures to those used by Matebesi-Ranthimo *et al*. (2014) were applied for analysis in the present study using the ASReml program (Gilmour *et al*., 2009). Therefore, fixed effects to be included in the operational model for each trait were tested and details of the models are described fully by Matebesi-Ranthimo *et al*. (2014). The variance components and ratios were estimated as described by Matebesi-Ranthimo *et al*. (2014). The correlations (genetic, phenotypic and environmental) of FEC with subjectively assessed wool and conformation traits were subsequently computed by fitting a series of two-trait and four-trait animal models to derive correlations between traits. These analyses included all the components found to be significant in the single-trait analyses.

Results and Discussion

The descriptive statistics for subjectively assessed wool and conformation traits are presented in Table 2. Detailed description and non-genetic factors for FEC can be found in a paper by Matebesi-Ranthimo *et al*. (2014) and will not be repeated here. Preliminary analysis of non-genetic effects indicated that selection line (1 - 4), birth type (single/multiple), sex (male/female), age of the dam in years (2 - 6), year of birth (1989 - 2012) and the sex by birth year interaction had a significant (P <0.05) effect on all subjectively assessed wool and conformation traits. This is in line with previous studies on the same flock (Cloete *et al*., 1998; Naidoo *et al*., 2004; Matebesi *et al*., 2009a).

Table 2 Descriptive statistics of data after editing from Tygerhoek Merino resource flock

Trait	N	Mean	SD	CV	Range
Subjective wool traits					
FCS	7167	31.29	6.50	20.77	1–50
PIGM	7159	31.00	9.32	30.01	1–50
WFS	6707	29.19	8.38	28.71	1–50
QUAL	7144	31.15	8.21	26.36	1–50
ROC	7141	32.68	7.87	24.08	1–50
COL	7135	29.34	7.22	24.61	1–50
OIL	7167	26.21	4.31	16.44	3–45
STAPL	7167	28.50	5.85	20.53	2–48
BANDP	7165	30.68	6.40	20.86	1–50
Subjective conformation traits					
TOT	6771	9.41	2.37	25.19	1–40
GEN	6770	29.61	7.12	24.05	1–50
HOCKS	6770	24.94	8.30	33.30	1–48
FQ	6771	23.39	6.69	28.60	1–49
PS	6789	32.61	6.75	20.70	1–50
TOPL	6769	30.45	7.50	24.63	1–50

N = number of records; SD = standard deviation; CV = coefficient of variation; FCS = face cover score; PIGM = pigmentation; WFS = woolly face score; QUAL = wool quality; ROC = regularity of crimp; COL = colour; OIL = oil; STAPL = staple formation; BANDP = belly and points; TOT = total fold score; GEN = general head conformation; HOCKS = hocks; FQ = front quarters; PS = pastern score; TOPL = topline.

The selection of models was carried out according to the log likelihood ratio test described in Matebesi-Ranthimo *et al*. (2014). The model including only the direct additive genetic effect of animal (σ^2_a) as a random factor fitted the data best for FCS, PIGM, WFS, ROC, COL, OIL, BANDP, HOCKS, FQ and PS. Model 3, which included direct (σ^2_a) and maternal genetic (σ^2_m) effects, as well as their covariance (σ_{am}) as random effects, fitted the data best for STAPL while Model 6, with only direct additive and dam permanent environmental effects (c^2), was the most appropriate model for GEN and TOPL. In contrast, previous results suggested that ROC, QUAL, COL and TOPL were influenced by direct and maternal genetic effects, as well as their covariance (Matebesi *et al*., 2009b).

All subjectively assessed wool and conformation traits were heritable with a range between 0.11 for FCS to 0.41 for PIGM for subjective wool traits and from 0.11 for PS and TOPL to 0.36 for TOT for subjective body conformation traits. A study done on the Merino National Progeny Test data (Groenewald *et al.*, 1999) yielded lower heritability estimates for corresponding traits (0.17 for COL and BANDP, 0.27 for QUAL, 0.32 for fold score, 0.09 for STAPL and 0.26 for HOCKS).

Table 3 Log likelihood ratios for random effects models fitted to subjectively assessed wool and conformation traits data of Tygerhoek Merino resource flock with the “best” model in bold

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Subjective wool traits						
FCS	**−5548.95**	−5548.95	−5548.75	−5548.95	N/C	−5548.95
PIGM	**−7619.84**	−7619.84	N/C	−7819.84	N/C	−7619.84
WFS	**−6325.32**	−6325.31	−6324.66	−6324.17	N/C	−6324.17
QUAL	**−6710.85**	−6710.62	−6709.51	−6710.96	N/C	−6710.96
ROC	**−7093.59**	−7093.59	N/C	−7093.59	N/C	−7093.59
COL	**−6091.47**	−6091.22	−6090.58	−6090.09	N/C	−6090.09
OIL	**−3369.42**	3368.34	−3368.77	−3368.05	N/C	−3368.05
STAPL	−4953.59	−4950.97	**−4948.91**	−4950.74	4948.60	−4951.51
BANDP	**−6089.33**	−6089.22	−6088.88	−6089.22	−6088.88	−6089.33
Subjective conformation traits						
TOT	**−8171.07**	−8170.41	−8169.92	−8170.14	N/C	−8170.53
GEN	−5087.45	−5083.53	−5083.32	−5081.93	N/C	**−5081.25**
HOCKS	**−6641.97**	−6641.80	−6641.08	−6641.80	−6641.08	−6641.99
FQ	**−5060.56**	−5060.56	−5059.15	−5060.35	−5059.44	−5060.35
PS	**−5056.45**	−5056.44	−5055.58	−5056.75	−5055.44	−5056.75
TOPL	−5564.41	−5563.47	−5562.67	−5561.63	−5562.58	**−5561.68**

N/C = no convergence; FCS = face cover score; PIGM = pigmentation; WFS = woolly face score; QUAL = wool quality; ROC = regularity of crimp; COL = colour; OIL = oil; STAPL = staple formation; BANDP = belly and points; TOT = total fold score; GEN = general head conformation; HOCKS = hocks; FQ = front quarters; PS = pastern score and TOPL = topline.

The heritability estimated currently for OIL (0.21 vs. 0.24) and FQ (0.18 vs. 0.21) was on the lower side compared with reports using Merino data from the national progeny test. Furthermore, some differences of heritability from this investigation and that of Matebesi *et al*. (2009a) on the same Merino resource flock were observed for QUAL (0.32 vs. 0.49) and ROC (0.12 vs. 0.28). These differences may be because of the use of different random effects models. Studies on Australian Merino flocks yielded a slightly higher h^2_a of 0.42 for wrinkle score than the current estimate (Mortimer *et al.*, 2009). The latter study also reported slightly higher estimates of h^2 for front legs and back legs compared with the corresponding traits studied in the present study.

The correlations among subjectively assessed traits did not differ from those reported in the previous study on the same Merino flock and therefore are omitted in the current investigations. Estimates of the genetic (r_g), phenotypic (r_p) and environmental (r_e) correlations from two-trait analyses for log transformed FEC with subjectively assessed wool and conformation traits are presented in Tables 6 and 7, respectively. The correlations involving FEC and subjectively assessed wool and conformation traits obtained from four-trait analyses did not differ substantially from those obtained from two-trait analysis, and will not be discussed. Genetic correlations between log transformed FEC and subjectively assessed wool and conformation traits were relatively small in magnitude, ranging from −0.33 for TOPL to 0.29 for STAPL. Most were not significant in relation to the corresponding standard errors. Attempts to find comparable literature resulted in only one published negligible genetic correlation of 0.003 between FEC and TOT (Cloete *et al*., 2007). The absolute magnitude of the corresponding correlation in the present study (0.15) is somewhat higher (Table 7). The direction of the derived correlation suggests that animals with high parasite burdens will also have more wrinkles; that is, the correlation is favourable. However, the comparable environmental and phenotypic correlations were consistently in the <0.05 range.

Table 4 (Co)variance components and ratios for subjectively assessed wool traits in Tygerhoek Merino resource flock

	FCS	PIGM	WFS	QUAL	ROC	COL	OIL	STAPL	BANDP
(Co)variance components									
σ^2_a	2.81	22.88	20.44	17.00	9.53	9.70	3.13	4.72	7.34
σ^2_m	-	-	-	-	-	-	-	0.56	-
σ_{am}		-	-	-	-	-	-	−0.80	-
σ^2_e	25.58	33.60	32.62	34.62	36.31	25.76	12.67	19.16	26.75
σ^2_p	28.39	56.47	53.06	51.63	45.84	35.46	15.80	24.07	34.10
Variance ratios									
h^2_a	0.10	0.41	0.39	0.33	0.21	0.27	0.20	0.20	0.22
SE	0.02	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02
h^2_m	-	-	-	-	-	-	-	0.04	-
SE	-	-	-	-	-	-	-	0.01	-
r_{am}	-	-	-	-	-	-	-	−0.38	-
SE	-	-	-	-	-	-	-	0.13	-

σ^2_a = direct additive genetic variance; σ^2_m = maternal additive genetic variance; σ^2_e = residual variance;
σ^2_{am} = covariance between direct and maternal additive variance; h^2_a= direct heritability; h^2_m= maternal heritability;
r_{am} = genetic correlation between direct, maternal additive genetic effects; SE = standard error.
See Table 1 for other abbreviations.

Table 5 (Co)variance components and ratios for subjective conformation traits in Tygerhoek Merino resource flock

	TOT	GEN	HOCKS	FQ	PS	TOPL
(Co)variance components						
σ^2_a	1.56	10.90	18.46	6.18	3.96	4.92
σ^2_{pe}	-	1.46	-	-	-	1.18
σ^2_e	2.92	25.16	41.69	29.49	31.92	37.04
σ^2_p	4.48	37.52	60.16	35.68	35.88	43.140
Variance ratios						
h^2_a	0.35	0.29	0.30	0.17	0.11	0.11
SE	0.02	0.03	0.03	0.02	0.02	0.02
c^2_{pe}	-	0.04	-	-	-	0.03
SE	-	0.01	-	-	-	0.01

σ^2_{cpe} = permanent environmental variance; c^2_{pe} = permanent environmental effect; FCS = face cover score;
PIGM = pigmentation; WFS = woolly face score; QUAL = wool quality; ROC = regularity of crimp; COL = colour;
OIL = oil; STAPL = staple formation; BANDP = belly and points; TOT = total fold score;
GEN = general head conformation; HOCKS = hocks; FQ = front quarters; PS = pastern score; TOPL = topline.

At the genetic level, only log transformed FEC was significantly related to OIL and STAPL, among all the subjectively assessed wool traits. The positive correlation between log transformed FEC and OIL suggested that sheep with a high quantity of internal nematodes are likely to have wool with excessive oil. South African research has indicated that excessive wool oil has an unfavourable effect on handling by increasing its harshness (Venter, 1981). Excessive oil also affects the appearance of wool owing to an undesirable discolouration and results in a lower wool clean yield (Venter, 1981). The positive genetic correlation of FEC with STAPL suggests that animals with higher parasite burdens were likely to have thicker and blockier staples. This genetic correlation may influence selection for wool quantity in a strategy that seeks to improve fleece weight while reducing FEC, as STAPL was favourably correlated to clean fleece weight on the genetic level (0.39; Matebesi *et al*., 2009b). In contrast, genetic correlations of STAPL with fibre diameter (FD: 0.59) and the coefficient of variation of fibre diameter (CVFD: 0.49) were unfavourable according to these authors. The direction of the derived genetic correlation between FEC and STAPL may thus be of concern as far as wool quantity is concerned. On the other hand, the possible deterioration of STAPL scores resulting from selection for reduced FEC could potentially benefit wool quality. Phenotypic correlations were significant and negative for FEC with WFS and ROC. In contrast, positive phenotypic correlations were observed for FEC with OIL, STAPL and BANDP in the current study.

Table 6 Genetic, phenotypic and environmental (± SE) correlations between faecal egg count and subjective wool traits in Tygerhoek Merino flock

Trait	Genetic (r_g)	Environment (r_e)	Phenotypic(r_p)
FEC(log+100) X			
Face cover score (FCS)	−0.25 ± 0.13	−0.05 ± 0.02*	−0.06 ± 0.01
Pigmentation (PIGM)	−0.09 ± 0.08	−0.01 ± 0.03	−0.02 ± 0.02
Woolly face score (WFS)	−0.11 ± 0.08	−0.03 ± 0.02	−0.04 ± 0.01*
Quality (QUAL)	−0.11 ± 0.09	0.02 ± 0.02	−0.01 ± 0.02
Regularity of crimp (ROC)	−0.18 ± 0.10	0.02 ± 0.02	−0.02 ± 0.01*
Colour (COL)	−0.10 ± 0.08	0.03 ± 0.02	−0.002 ± 0.01
Oil (OIL)	0.18 ± 0.09*	−0.01 ± 0.02	0.03 ± 0.01*
Staple formation (STAPL)	0.29 ± 0.10*	0.00 ± 0.02	0.05 ± 0.01*
Belly and points (BANDP)	0.13 ± 0.10	0.02 ± 0.02	0.04 ± 0.01*

* = significant correlation.

The subjectively assessed conformation traits were largely independent of FEC at the genetic level. The only noteworthy genetic correlation of −0.33 occurred between TOPL and FEC. This correlation suggests that low scores for TOPL are likely to be found in individuals that have a high population of intestinal nematodes, rendering the correlation favourable. Phenotypic and environmental correlations of FEC with subjective conformation traits were mostly negative (i.e. favourable), significant in a number of instances, but consistently small in magnitude at <0.10.

Table 7 Genetic, phenotypic and environmental (± SE) correlations between faecal egg count and subjective conformation traits in Tygerhoek Merino flock

	Genetic (r_g)	Environment (r_e)	Phenotypic(r_p)
FEC(log+100) X			
Total fold score (TOT)	0.15 ± 0.08	−0.04 ± 0.02*	0.01 ± 0.016
General head conformation (GEN)	0.02 ± 0.09	−0.05 ± 0.02*	−0.04 ± 0.02*
Hocks(HOCKS)	0.03 ± 0.09	−0.07 ± 0.02*	−0.05 ± 0.01*
Front quarters (FQ)	−0.13 ± 0.11	−0.03 ± 0.02	−0.05 ± 0.01*
Pastern score (PS)	−0.16 ± 0.13	0.03 ± 0.02	0.01 ± 0.01
Topline (TOPL)	−0.33 ± 0.11*	−0.04 ± 0.02*	−0.08 ± 0.01*

* = significant correlation.

Conclusion

The study confirmed previous results from the same flock that subjective wool and body conformation traits are heritable and variable, and should thus respond to selection, if desired. The majority of subjective traits were not related to FEC at genetic level, and two of the three significant genetic correlations (those for OIL and TOPL) were favourable. The positive genetic correlation of FEC with STAPL suggests that wool weight may be compromised by selection for reduced FEC, but that the quality of the wool (as reflected by FD and CVFD) may be enhanced. There was thus limited evidence of subjectively assessed traits being impaired by selecting South African sheep flocks for resistance to gastro-intestinal nematodes, as reflected by FEC.

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