THE TURRETFIELD SHEEP BREEDING PROJECT: MESSAGES ON PHENOTYPIC AND GENETIC PARAMETERS FOR SOUTH AUSTRALIAN MERINO SHEEP

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INTRODUCTION

Industry practice in many South Australian Merino ram breeding flocks is to initially performance record rams at 10 to 12 months of age with 6 to 8 months of wool growth. A selected fraction of these rams is re-tested about 6 months later, and a final selection of sires is then made. Breeding values at such early ages (i.e. 10 to 12 and 16 to 18 months) are used in the selection of sires to improve the lifetime productivity of progeny in commercial flocks. However, most of the genetic parameter estimates for Merino sheep have been based on records obtained at 15 to 18 months, with 12 months' wool growth, and with strains other than the South Australian Merino. The aim of the Turretfield sheep breeding project is to obtain reliable phenotypic and genetic parameters at the ages in which the sheep are commonly performance recorded in ram breeding flocks, and during the lifetime of breeding ewes. Because of the widespread influence of the South Australian Merino strain, the outcomes of this project are applicable to over 40 per cent of the national flock. In this paper we report some results of a recently completed phase of the project (data collection on four drops of 10 and 16 month old rams), and of a study of dental characters in 5 and • year old ewes.

MATERIALS AND METHODS

Location and sheep

The project is being conducted at Turretfield Research Centre (TRC), South Australian Research and Development Institute, located near Rosedale, 55 km north-east of Adelaide. The centre is in the cereal-animal zone, with an average annual rainfall of 464 mm, of predominantly winter (May to September) incidence.

A resource flock of 2000 South Australian Merino strain ewes representative of the Bungaree and Collinsville family groups was established at TRC in 1988. For each family group, ewes were purchased from two studs (500 ewes from each stud). The studs were chosen on the basis of their impact as ram sellers in the Merino sheep industry. The Bungaree family group was represented by Anama and East Bungaree studs, whereas the Collinsville family group was represented by Collinsville and Southrose studs.

Each year about fifteen rams were purchased from each of the cooperating studs. The sire selection procedures depended on the information available in the individual studs. Random selections were made

from rams performance tested at 10 to 12 months of age (Anama and Southrose), or from various price grades established by the stud master (Collinsville and East Bungaree).

The results presented in this paper are from two data sets originating from the project:

Data set 1 Corresponds to 2200 young rams born over four years (1989, 1990, 1991 and 1992), offspring of 162 sires.

Data set 2 Corresponds to 210 breeding ewes (5 and • years old) born in 1989, offspring of 17 sires.

Management and records

The management program for the flock reflected, as far as practicable, current South Australian stud Merino industry practices. Mating took place for an eight week period in November-December. Each year, twelve sires from each stud were single-sire mated, on a within stud basis, to 40 randomly allocated ewes. Lambs were born in April-May and weaned at an average age of 13 weeks in early August. Subsequently, male and female lambs were managed separately. All lambs were shorn at about four months of age, soon after weaning. Thereafter, the ram progeny were shorn and their performances recorded at 10 (February) and 16 (August) months of age, and they were sold for slaughter after the 16 month assessment. The ewe progeny were only shorn at 16 months of age, and every 12 months thereafter, up to 5 and • years of age, when they were discarded from the project.

For each experimental lamb born, the identity and age of the dam, the date of birth, the type of birth and of rearing, as well as all management details were recorded. The complete list of characters recorded in this project is shown in the paper by Gifford et al. (1993). Tables 1 and 2 list the young rams' and the 5 and • year old ewes' characters dealt with in this paper, respectively. The ewes' dental records were taken in November 1994, after their final lambing and shearing in April-May and August, respectively.

Analyses

Young rams Phenotypic and genetic parameters were estimated by fitting a sire model to the data. The mathematical model included the fixed effects of year of birth, stud, age of dam, and type of birth and rearing class (except for birth coat score, for which instead of type of birth and rearing, only type of birth was fitted). Day of birth of the individual (within the lambing period) was fitted as a linear covariate. Sires were treated as a random effect nested within year of birth and stud. Variance and covariance components were calculated by restricted maximum likelihood using PROC Mixed in SAS (1992).

Preliminary analyses included two-way interactions among the above mentioned fixed effects. Because the great majority of interactions were non-significant or could be considered of spurious origin they were deleted from the model for this first report of results.

Ewes (5 and • years old) The data being collected on adult breeding ewes will enable the estimation of phenotypic and genetic parameters for all characters recorded. However, the number (17) of sires represented in the 1989 ewe drop at 5 and • years of age is too small for the estimation of reliable parameters at the present stage. Instead, residual correlations were calculated between the production and the dental characters listed in table 2, using the MANOVA option in SAS (1985). The model fitted included the effects of stud, sire within stud, age of dam, and type of birth and rearing. Residual correlations (which are akin to phenotypic correlations) were estimated from the error sum of squares and cross-products matrix in the analysis described above.

RESULTS AND DISCUSSION

General

The Turretfield sheep breeding project will eventually enable the estimation of environmental effects and heritabilities, and of the correlation of each character with every other character recorded at any age. However, for reasons of space and because the information on adult ewes is still being collected, only a small sub-set of the information generated is given here. Firstly, some overall information pertaining to records on young rams is presented and briefly discussed. Secondly, some specific situations, for the examination of which the current data set is particularly appropriate, are studied.

Phenotypic and genetic parameters in 10 and 16 month old rams (Data set 1)

Table 1 shows the mean and phenotypic standard deviation for the characters examined. These were arbitrarily divided into two groups, namely, those objectively measured and those subjectively assessed. The scoring system used for the subjectively assessed characters is shown in the Appendix. Birthcoat information is included in the column corresponding to 10 month old rams, but it was recorded at birth. Fibre diameter stability was calculated as FD at 16 months minus FD at 10 months.

Table 3 shows the heritabilities, as well as the correlations between records taken at 10 months and those taken at 16 months. Virtually all of the objectively measured characters had moderate to high heritability at both ages, with the exception of dust penetration. Subjectively assessed characters also had moderate to high heritabilities, except for conformation and leg scores, which had the lowest values. With very few exceptions (i.e. dust penetration) the genetic correlations between 10 and 16 month old records were moderate to very high. The values corresponding to the subjectively assessed characters were particularly high.

The parameter values shown in tables 1 and 3 (plus other that can be generated from our data) are essential in the formulation of effective selection strategies compatible with current stud industry practice. The strategies may include the use of subjectively assessed characters as selection criteria. The information could be used in a package such as OBJECT (Semple et al. 1994) in the design of a version specifically targeting South Australian Merinos.

Fibre diameter stability (Data set 1)

Fibre diameter stability (FDS), also often called micron 'blow out', is of special concern to South Australian Merino breeders. It is a measure of an animal's tendency to become stronger (or finer) with age, relative to the mean of its contemporary group. Breeders wishing to reduce FD, would like to be able to select animals that measure below average at a young age, and that retain that position later in life. They wish to avoid those that are below average at, say, 10 months, but become stronger than average at a later age.

FDS was measured as the difference between FD at 16 months and at 10 months. Table 4 shows the heritability estimate of FDS, and the correlations with a number of characters of interest. The heritability of FDS was not as high as for some other wool traits, but it was moderate and in close agreement with an estimate (0.23) reported by Atkins (1992) for FDS recorded in ewes.

The correlations with other characters were generally low, both at the phenotypic and at the genetic level. The correlations with fibre diameter variability measures (FDSD and FDCV) were particularly disappointing, given that these characters have been sometimes suggested as indicators of FDS. In fact, the genetic correlation between FDS and FDCV was of opposite sign to that implied by those claiming that lower FDCV is associated with reduced micron 'blow out'. This is in agreement with findings reported by Taylor and Atkins (1992). The genetic correlations of FDS with skin quality and lock were in a favourable direction and could be useful.

Table 1. Means and phenotypic standard deviations (s_P) reported for young rams

CHARACTERS	AGE AT MEASUREMENT			
	10 months		16 months	
	Mean	s_P	Mean	s_P
Objectively measured				
Greasy fleece weight (GFW), kg	3.43	0.53	4.07	0.59
Yield (YLD), %	65.8	5.13	72.2	4.69
Clean fleece weight (CFW), kg	2.27	0.40	2.93	0.44
Fibre diameter (FD), µm	21.3	1.57	22.6	1.76
Standard deviation of FD (FDSD), µm	5.03	0.71	5.34	0.68
Coefficient of variation of FD (FDCV), %	23.6	2.63	23.6	2.68
Crimp frequency (CF), no. per 25 mm	8.8	1.2	8.1	1.3
FD stability (FDS), µm			1.31	1.25
Staple length (SL), mm	57.6	5.40	65.2	6.41
Staple strength (SS), N/ktex	42.3	10.2	45.5	10.4
Dust penetration-back (DPB), mm	2.67	0.79	1.81	0.53
Dust penetration-mid side (DPM), mm	2.28	0.54	1.97	0.60
Live weight (LW), kg	42.3	5.42	54.5	6.69
Scrotal circumference (SC), cm	26.3	3.15	31.8	2.74
Subjectively assessed[A]				
Birth coat (BC)	2.75	0.97		
Face cover (FC)	1.86	0.46	2.02	0.57
Neck wrinkles (NWS)	3.36	0.75	3.40	0.79
Body wrinkles (BWS)	2.41	0.61	2.56	0.68
Conformation (CONF)	2.71	0.69	2.71	0.71
Wool cover (COVER)	2.80	0.59	2.90	0.51
Lock (LCK)	2.89	0.57	2.93	0.56
Skin quality (SQ)	2.83	0.76	2.81	0.67
Handle (HNDL)	2.98	0.71	3.17	0.75
Visual colour (VCOL)	3.18	0.58	3.17	0.60
Crimp definition (CD)	2.82	0.85	2.51	0.88
Wool condition (COND)	2.75	0.71	2.68	0.66
Front legs (FLEG)	3.55	0.64	3.41	0.70
Back legs (BLEG)	3.13	0.56	3.30	0.58
Visual grade (VG)	2.59	0.80	2.48	0.93

[A] See Appendix for scoring system of subjectively assessed characters

Table 2. Means and standard deviations (SD) reported for 5 and • year old ewes (1994 recording)

CHARACTERS	Mean	SD
Production		
Yield(YLD), %	65.9	5.58
Clean fleece weight(CFW), kg	4.81	0.76
Fibre diameter(FD), μm	24.9	2.07
Number of lambs born(NLB)[A]	1.19	0.61
Number of lambs weaned(NLW)[A]	0.95	0.61
Live weight(LW), kg	63.6	6.96
Dental[B]		
Overall teeth score(OTS)	4.53	0.7
Evenness of wear(E)	3.09	1.25
Firmness(F)	2.83	0.42
Length of left central incisor(LI), mm	18.1	2.32
Line-up of teeth and pad(LU)	0.64	0.49
Number of missing incisors(NM)	0.25	0.63

[A] Per ewe present at lambing [B] See Appendix for scoring system of dental characters

The greatest genetic correlation in table 4 was with FD itself, indicating that selection for lower FD should also result in a lower value for FDS (i.e. reduced micron 'blow out'). Note that the phenotypic and genetic correlations between FDS and FD were of opposite sign, due to a moderate negative (-0.51) environmental correlation.

The moderate heritability of FDS between 10 and 16 months indicates that the character should respond to selection. The use of half-sib information, in addition to own performance, is advisable to try to avoid incorrect rankings due to measurement error of FD at 10 or (and) 16 months. The information currently being collected in the Turretfield sheep breeding project will enable the estimation of the genetic correlation between FDS measured at 10 to 16 months of age in rams, and that occurring among adult ewes. It will be valuable to find out whether FDS between 10 and 16 months in rams can be used as a reliable predictor of the same phenomenon in adult ewes.

Table 3. Heritabilities and correlations between characters at 10 and 16 months

CHARACTERS	Heritabilities		Correlations between 10 and 16 mo records	
	10 mo	16 mo	Phenotypic	Genetic
Objectively measured				
Greasy fleece weight (GFW), kg	0.58	0.44	0.55	0.45
Yield (YLD), %	0.57	0.72	0.56	0.80
Clean fleece weight (CFW), kg	0.59	0.51	0.55	0.52
Fibre diameter (FD), µm	0.45	0.59	0.72	0.91
Standard deviation of FD (FDSD), µm	0.44	0.58	0.57	0.95
Coefficient of variation of FD (FDCV), %	0.59	0.61	0.62	0.92
Crimp frequency (CF), no. per 25 mm	0.40	0.29	0.50	0.84
FD stability (FDS), µm		0.19		
Staple length (SL), mm	0.32	0.48	0.61	0.71
Staple strength (SS), N/ktex	0.25	0.47	0.23	0.68
Dust penetration-back (DPB), mm	0.14	0.18	0.14	0.32
Dust penetration-mid side (DPM), mm	0.32	0.21	0.17	0.54
Live weight (LW), kg	0.46	0.50	0.78	0.89
Scrotal circumference (SC), cm	0.35	0.41	0.58	0.62
Subjectively assessed				
Birth coat (BC)	0.66			
Face cover (FC)	0.26	0.41	0.48	0.87
Neck wrinkles (NWS)	0.42	0.32	0.47	0.98
Body wrinkles (BWS)	0.38	0.31	0.42	0.80
Conformation (CONF)	0.19	0.15	0.41	1.00
Wool cover (COVER)	0.38	0.33	0.31	0.65
Lock (LCK)	0.39	0.33	0.40	0.74
Skin quality (SQ)	0.36	0.24	0.33	0.76
Handle (HNDL)	0.21	0.43	0.33	0.73
Visual colour (VCOL)	0.27	0.36	0.33	0.79
Crimp definition (CD)	0.53	0.48	0.49	0.89
Wool condition (COND)	0.35	0.29	0.35	0.78
Front legs (FLEG)	0.20	0.23	0.22	0.58
Back legs (BLEG)	0.17	0.19	0.29	0.89
Visual grade (VG)	0.34	0.25	0.47	0.76

Table 4. Heritability of fibre diameter stability and its correlation with some characters recorded at 10 months[^]

Heritability	0.19	
Correlations with:	Phenotypic	Genetic
Birth coat score	-0.02	-0.10
10 mo old record of:		
YLD	0.06	0.20
CFW	-0.06	-0.15
FD	-0.24	0.36
FDSD	0.05	0.03
FDCV	0.08	-0.16
SLCV	-0.03	0.12
Skin quality	-0.07	-0.21
Lock	-0.05	-0.29
Handle	0.02	0.07
Crimp definition	0.03	0.13
Body wrinkles	-0.03	0.03

[^] See table 1 for meaning of symbols, and the Appendix for scoring system of subjectively assessed characters, except for SLCV (coefficient of variation of staple length)

Skin quality (Data set 1)

Skin quality is often the focus of discussions and controversies about breeding methods for improved wool production. In the Turretfield project skin quality was scored by a professional sheep classer (Mr David Jones). The character may be defined as the freeness of the skin (pliability) and its wool growing potential. The assessment is based on a combination of visual (when opening the fleece) and tactile (when the skin is felt) senses. Skin quality was assessed on top of the mid-rib, half way between the top-line and the mid-side.

Skin quality had a moderate to high heritability (Table 5), and the genetic correlation between records taken at both ages (10 and 16 months) was high (Table 3). Table 5 also shows the correlation between skin quality and a number of other characters. There was a remarkable consistency between the estimates at both ages. Generally, the correlations were very low to low, but there were exceptions. The highest value was with wool condition, followed by CFW and lock, in that order. The usefulness of the association of skin quality with lock and wool condition would depend on the merit of having higher scores for the two latter characters. Skin quality could be a valuable indirect indicator of CFW, but not of the other objectively measured characters included in table 5. Contrary to statements sometimes made, selection for CFW should result in an 'improvement' of skin quality, not a deterioration. The information on skin quality supports the notion that classer skills and objective measurement can be beneficially combined.

Table 5. Heritability of skin quality and its correlation with some characters [A]

Heritability	0.36[B] 0.24[C]	
Correlations with:	Phenotypic	Genetic
YLD	0.06	0.09
	0.1	0.23
CFW	0.4	0.65
	0.37	0.57
FD	-0.01	0.07
	0.04	0.0
FDSD	-0.02	0.03
	-0.01	-0.1
FDCV	-0.01	-0.03
	-0.04	-0.14
SS	0.05	0.1
	0.11	0.22
Lock	0.24	0.55
	0.18	0.38
Handle	0.26	0.39
	0.18	0.29
Crimp definition	-0.06	-0.16
	-0.09	-0.02
Wool condition	0.56	0.87
	0.37	0.69

[A] See table 1 for meaning of symbols, and the Appendix for scoring system of subjectively assessed characters [B] Records taken in 10 mo old rams [C] Records taken in 16 mo old rams

Structural soundness

Ram breeders and wool growers commonly pay attention to sheep attributes related to structural soundness. This is done for a number of reasons, which include the predicted ability of the sheep to: (i) walk in their search of forage and water, (ii) perform reproductive functions, (iii) carry a heavy fleece, (iv) forage, probably in low quality and (or) quantity pastures, and (v) generally withstand the rigours of the environment. The visual appeal of the sheep can also be an important consideration. Scientists have paid less attention to structural soundness than to production characters (e.g. fleece weight) in sheep, but there is very limited documented evidence to justify that attitude. In the Turretfield project a number of characters related to structural soundness are being recorded, and some initial results are reported here.

Rams at 10 and 16 months of age (Data set 1)

Three of the structural soundness characters we recorded in young rams are conformation, front legs and back legs. Table 3 shows that generally they had low to moderate heritability. They can respond to selection, but will do so more slowly than standard production characters (e.g. fleece weight, fibre diameter). The repeatability (phenotypic correlation) for the leg scores was low. This indicates that the relative score for this character changed with age, possibly due to the animals' own development or to hoof

growth at the time of scoring. Therefore, intense culling for leg faults at an early age could be unwise. Similar, but less severe (moderate repeatability), problems could be found with conformation.

Table 6. Phenotypic(P) and genetic(G) correlations between structural soundness and production characters

A	Conformation		Front legs		Back legs	
	P	G	P	G	P	G
CFW	0.4[B] 0.4[C]	0.6 0.51	0.05 0.11	0.15 0.32	0.14 0.12	0.35 0.07
FD	0.16 0.23	0.25 0.39	-0.01 0.11	-0.08 0.17	0.02 0.06	0.1 0.22
SS	0.06 0.12	0.26 0.16	0.01 0.06	-0.08 -0.05	0.02 0.07	-0.25 0.23
LW	0.51 0.54	0.72 0.94	0.03 0.18	0.18 0.21	0.2 0.22	0.56 0.37

[A] See table 1 for meaning of symbols [B] Records from 10 mo old rams [C] Records from 16 mo old rams

Table 6 shows the phenotypic and genetic correlations between the above mentioned structural soundness characters and some production characters. The greatest and most consistent correlations (in descending order) were those of conformation with LW and CFW, and of back legs with LW. Better scores were associated with greater LW and CFW. Other correlations involving leg scores were low and sometimes inconsistent between ages (e.g. back legs with SS). With one exception (conformation and FD), there were no serious antagonisms between structural soundness and production characters. This is in broad agreement with the findings of Lewer et al. (1995). Selection for production should not necessarily lead to a deterioration of structural soundness, and vice versa. In the case of conformation and FD, the correlations were in the wrong direction. South Australian breeders selecting for lower FD could experience a deterioration (according to current standards) in conformation, if the character were left unchecked.

Ewes (5 and • years old) (Data set 2)

Wear rate of teeth is commonly an important culling criterion among adult ewes. Ewes in which the teeth: (i) look generally 'normal', (ii) are evenly worn, (iii) are firm, (iv) do not show excessive length of the central incisors, (v) are well aligned with the upper pad, and (vi) are all present, are preferred, assuming that they are better able to forage and more productive.

In the Turretfield sheep breeding project adult ewes are kept until they are 5 and • years old. The opportunity is being taken to record the dental characters listed in table 2 so that their heritability and association with other characters can be estimated. Table 7 shows the residual correlations between dental and some production characters. Without exception, all correlations were very low, indicating that none of the dental attributes examined was associated with production. This result is consistent with findings reported by Baker et al. (1986) in New Zealand. However, two features of our data have to be kept in mind. Firstly, although there was variation in all of the dental characters studied (see table 2), the general

condition of the teeth was good. Secondly, the production records were taken before the dental characters were assessed, and not after, as would have been more desirable. Neither of these two features seriously undermines the value of our study. The results suggest that culling of ewes based on any of the dental characters examined would have been a wasted effort.

Table 7. Correlations between dental and production characters in 5 and • year old ewes

A	YLD	CFW	FD	NLB	NLW	LW
Overall teeth score	0.03	0.01	0.09	0.03	-0.01	0.09
Evenness of wear	0.1	0.04	0.06	-0.02	-0.02	0.05
Firmness	0.01	-0.03	-0.03	0.17	0.04	0.11
Length of left central incisor	-0.08	-0.06	-0.01	0	-0.07	0.03
Line-up of teeth and pad	0.06	0.04	-0.13	-0.01	0.05	0.03
Number of missing incisors	-0.07	-0.1	0.01	0.04	0.08	-0.13

[A] See table 2 for meaning of symbols

CONCLUDING REMARKS

The Turretfield sheep breeding project is generating information that should enable the design of more efficient genetic improvement programs for the South Australian Merino. The information is both comprehensive and reliable, given the very broad range of characters recorded and the rigorous design, sampling and conduct of the experiment. Any of the aspects dealt with in this paper could be examined in greater depth than what was possible here. The participation of a Sheep Classer in the project adds a new dimension to the research. Some of the results are uncovering hidden potential for the combined use of classer skills and objective measurement in genetic evaluation services for Merino sheep. By contrast, some traditional practices (such as culling for structural soundness) should perhaps be re-examined in the light of our findings.

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APPENDIX Scoring system for subjectively assessed characters

Birth coat (BC)	1 (no halo hairs),...., 7 (all long strait fibres)
Face cover (FC)	1 (open face),...., 5 (muffled face)
Neck wrinkles (NWS)	1 (plain),...., 5 (very wrinkly)
Body wrinkles (BWS)	1 (plain),...., 5 (very wrinkly)
Conformation (CONF)	1 (worst),...., 5 (best)
Wool cover (COVER)	1 (very slack),...., 5 (very dense)
Lock (LCK)	1 (tippy, hairy),...., 5 (square, blocky)
Skin quality (SQ)	1 (very tight),...., 5 (best, pliable)
Handle (HNDL)	1 (harsh, brittle),...., 5 (very soft)
Visual colour (VCOL)	1 (yellow),...., 4 (lustrous white)
Crimp definition (CD)	1 (very well defined),...., 5 (crimp hardly visible)
Wool condition (COND)	1 (very dry),...., 5 (greasy)
Front legs (FLEG)	1 (worst),...., 5 (best)
Back legs (BLEG)	1 (worst),...., 5 (best)
Visual grade (VG)	1 (best),...., 4 (worst)

Overall teeth score(OTS)	1 (worst, very poor condition),...,5 (best, sound)
Evenness of wear(E)	1 (very un-even),...., 5 (even)
Firmness(F)	1 (very loose),...., 3 (firm)

Teeth and pad line-up(LU)-1 (pad protrudes forward), 0 (central incisors meet pad correctly, 0 (incisors protrude forward from pad)