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Use of part records in Merino breeding programs — the inheritance of wool growth and fibre traits during different times of the year to determine their value in Merino breeding programs

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Abstract. Fibre diameter can vary dramatically along a wool staple, especially in the Mediterranean environment of southern Australia with its dry summers and abundance of green feed in spring. Other research results have shown a very low phenotypic correlation between fibre diameter grown between seasons. Many breeders use short staples to measure fibre diameter for breeding purposes and also to promote animals for sale. The effectiveness of this practice is determined by the relative response to selection by measuring fibre traits on a full 12 months wool staple as compared to measuring them only on part of a staple. If a high genetic correlation exists between the part record and the full record, then using part records may be acceptable to identify genetically superior animals. No information is available on the effectiveness of part records. This paper investigated whether wool growth and fibre diameter traits of Merino wool grown at different times of the year in a Mediterranean environment, are genetically the same trait, respectively. The work was carried out on about 7 dyebanded wool sections/animal.year, on ewes from weaning to hogget age, in the Katanning Merino resource flocks over 6 years.

Relative clean wool growth of the different sections had very low heritability estimates of less than 0.10, and they were phenotypically and genetically poorly correlated with 6 or 12 months wool growth. This indicates that part record measurement of clean wool growth of these sections will be ineffective as indirect selection criteria to improve wool growth genetically. Staple length growth as measured by the length between dyebands, would be more effective with heritability estimates of between 0.20 and 0.30. However, these measurements were shown to have a low genetic correlation with wool grown for 12 months which implies that these staple length measurements would only be half as efficient as the wool weight for 6 or 12 months to improve total clean wool weight. Heritability estimates of fibre diameter, coefficient of variation of fibre diameter and fibre curvature were relatively high and were genetically and phenotypically highly correlated across sections. High positive phenotypic and genetic correlations were also found between fibre diameter, coefficient of variation of fibre diameter and fibre curvature of the different sections and similar measurements for wool grown over 6 or 12 months. Coefficient of variation of fibre diameter of the sections also had a moderate negative phenotypic and genetic correlation with staple strength of wool staples grown over 6 months indicating that coefficient of variation of fibre diameter of any section would be as good an indirect selection criterion to improve stable strength as coefficient of variation of fibre diameter for wool grown over 6 or 12 months. The results indicate that fibre diameter, coefficient of variation of fibre diameter and fibre curvature of wool grown over short periods of time have virtually the same heritability as that of wool grown over 12 months, and that the genetic correlation between fibre diameter, coefficient of variation of fibre diameter and fibre curvature on part and on full records is very high (r_g >0.85). This indicates that fibre diameter, coefficient of variation of fibre diameter and fibre curvature on part records can be used as selection criteria to improve these traits. However, part records of greasy and clean wool growth would be much less efficient than fleece weight for wool grown over 6 or 12 months because of the low heritability of part records and the low genetic correlation between these traits on part records and on wool grown for 12 months.

Introduction

About 50% of the national Merino flock are found in the Mediterranean environment of southern Australia. This environment experiences severe fluctuations in food supply with sparse green feed in winter, abundant green feed in spring, abundant dry feed in summer and sparse dry feed in autumn.

Adams *et al*. (1996) found that the rate of wool grown during summer–autumn (on dry feed) on identical twin sheep, bears no significant relationship to the rate of wool grown by the same animals during winter–spring (on green feed) periods. A significant relationship exists between wool grown by sheep on similar feeds. The phenotypic correlation

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between fibre diameter of wool produced on dry feed and fibre diameter (FD) of wool produced on green feed was particularly low (r_p = 0.12 between FD on summer and winter feed and –0.14 between autumn and winter feed), but much higher (r_p = 0.7) on similar feed types. While the latter figure agrees with accepted repeatability estimates of FD of 0.7 (Turner and Young 1969), the correlation comparing the 2 growth periods is much lower. These results indicate that different mechanisms may control wool growth on dry and on green feed. It is common practice for stud breeders to select rams on the basis of 7 months of wool production over the summer–autumn period, primarily on dry feed. If the genetic correlation is of the same order, then these results indicate that animals selected on dry feed may not be the same animals a breeder would have selected on green feed.

The implications of this practice for the genetic improvement of the flock cannot be predicted from current knowledge but may have a substantial impact on the rate of genetic improvement of wool production. This paper reports the inheritance of, and the phenotypic and genetic correlation between wool production and wool quality traits during different times of the year to determine whether selection on part-records can be used effectively to increase genetic merit for total production.

Material and methods

The Merino genetic resource flock at the Great Southern Agricultural Research Institute (GSARI), Katanning, Western Australia, was established in 1981 and originated from 12 different studs from 3 bloodlines. The bloodlines were Peppin, Collinsville and Bungaree and each bloodline was represented by 4 studs from Western Australia. In 1986 another 4 studs were added, representing the Performance Sheep Breeders. Each stud was represented by 80 breeding ewes that were single sire-mated to 4 rams every year. This resulted in a total of 1280 ewes that were mated to 64 sires per year. Every year 3 rams were bought from each of the original studs, and 1 previously used ram per stud was again used in consecutive years to generate genetic links across years. Replacement ewes were born within this flock and were randomly selected from within each group. No culling was applied except for obvious anatomically abnormalities or coloured wool.

Ewe hoggets, born during April and May from 1986 to 1991 were used in this study. A total of 2803 ewes were available. They were weaned in August and shorn soon afterwards. The ewes were dyebanded about every 6–8 weeks over 12 months up to hogget shearing according to the method of Ellis (1986) as adapted from Wheeler *et al.* (1977). The amount of wool grown as measured by staple length growth (SLG mm/day) was determined by measuring the distance between the previous dyeband and the skin with a ruler. The next dyeband was applied after measurement. No greasy wool growth length measurements are available for the first section of the 1986 born animals.

The animals were shorn 6 months after weaner shearing in February and again 6 months later in August at hogget age. Wool growth was recorded at 6-month intervals as clean fleece weight (CFW_Feb and CFW_Aug) and a wool staple was also collected from a midside sample on each fleece. The staples were conditioned at a temperature of 20°C and relative humidity of 65% for 24 h (IWTO 1996) and then tested for fibre diameter (FD_Feb and FD_Aug), coefficient of variation of fibre diameter (CV_Feb and CV_Aug) and fibre curvature (CUR_Feb and CUR_Aug) with the Optical Fibre Diameter Analyser (OFDA2000) of Brims (1997). Ten wool staples were pulled from each midside wool sample and tested for staple strength (SS_Feb and SS_Aug) using an Agritester. In some cases the staples were too short and therefore it was not possible to determine staple strength on all the samples.

The dyebanded wool samples were removed with electric clippers before shearing. A staple with clear dyebands was also pulled and cut with a guillotine into different sections at the dyebands. This resulted in 5–7 sections per staple. The position of the different dyebands on the staple are indicated in Figure 1 for each year. Staples were grouped according to time of the year as indicated in Figure 1. The staple sections were conditioned at 20°C and 65% relative humidity for 24 h. The sections were then weighed and washed with hexane, dried by drawing air over the sample and reconditioned for 24 h. The sections were weighed again to obtain clean yield to determine clean wool growth (CWG) of each section. CWG of each section was calculated as a percentage of the sum of the weights of the clean wool of the different sections of each staple divided by the number of days between dyebands (%/day).

Average clean fleece weight (CFW_Total) over 12 months was determined by adding the 6 months CFW of each animal shorn in February and August. Average fibre diameter (FD_Total) over the 12-month period was determined by calculating a weighted average FD using the FD measurements from the February and August shearing.

Average FD, CV and CUR for each section were measured with the OFDA2000. Table 1 indicates the list of measurements that were collected on each animal and the number of measurements on each section.

Statistical analyses

The sections were grouped according to dyeband position to ensure that the time of wool growth of the different sections, agreed as close as possible to each other across years (Fig. 1). Most years had 7 sections except for 1988 and 1989 that only had 5 sections because less dyebands were applied in these years. Preliminary analyses were carried out by taking out the data of the larger sections 4 and 5 of the animals born in 1988 and 1989. However, with or without these sections the genetic parameters changed very little. Thus the final dataset included all the available records on all the dyebanded sections as indicated in Figure 1.

The ASREML program (Gilmour *et al.* 1999) was used to analyse the data. An animal model was fitted with birth year (1986–91), age of the dam (2–6 years), birth status (single or twin) and stud (1–16) as fixed effects. Day of lambing (DOL) was fitted as a covariate within year. All 2-way interactions were also fitted initially but only the significant interactions were left in the final model. Permanent environmental and genetic maternal effects were also fitted as additional random effects but both these were not significant for any trait as tested by the likelihood ratio test (Lynch and Walsh 1998) and were therefore left out of the final model.

Results

Environmental factors

Table 2 shows the mean values, number of records, *F*-values and level of significance of the different environmental factors (year of birth, age of the dam, stud, birth status, DOL) and their interactions for each trait.

Year of birth had a highly significant ($P<0.001$) effect on all traits except for CV6. All the other traits were significantly ($P<0.05$) affected by either age of the dam, birth status of the lamb, stud and DOL, or by a combination of these factors. These factors are known to cause normal variation and have been extensively described in the literature (Turner and Young 1969).

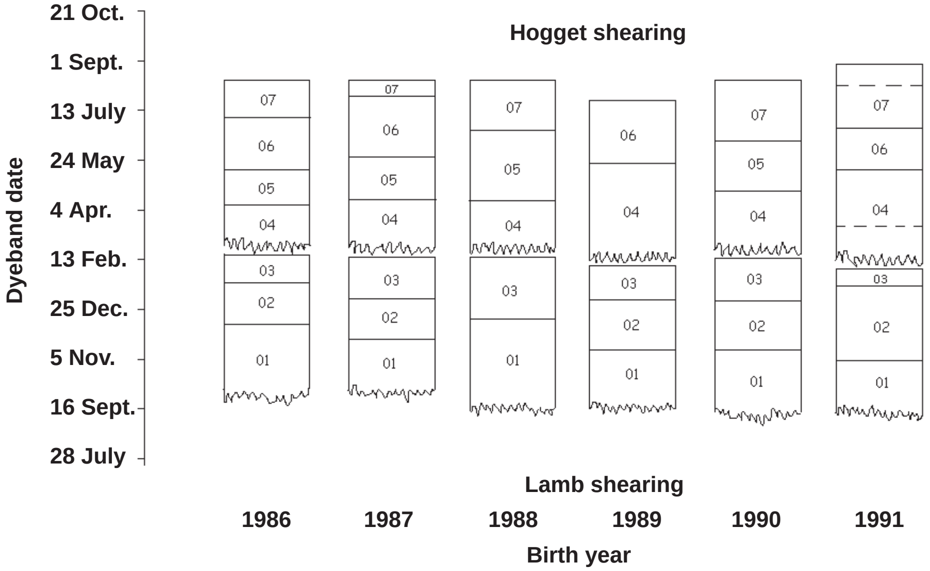

Figure 1. Schematic diagram indicating the position of the dyebands for each year.

Table 2 shows that FD followed the characteristic profile pattern for Mediterranean environments during the year with an average of 22.2 µm in section 1 (November), a decrease to a minimum of 17.6 µm in April and a further increase to 20.9 µm in August. Except for CUR3, fibre curvature displayed an inverse pattern to that found for FD.

Phenotypic variation and environmental correlations

Phenotypic variation and environmental correlations between staple length wool growth (SLG) at different times of the year is presented in Table 3. The environmental correlations of SLG are in general very low and in 1 case negative (–0.02 between SLG4 and CFW_Feb) but it was not significantly different from 0 as indicated by the standard error. This implies that positive environmental effects on SLG at any time of the year will have a very small positive effect on SLG at other times and over the total wool growth period.

The phenotypic variation and environmental correlations between adjacent wool growth periods for the 7 sections for CWG, the environmental correlation of the section traits for CFW grown over 6 months (for February and August), and

Table 1. Data records collected on each animal

Trait	Abbreviation	Unit
12 months wool measurements		
Clean fleece weight over 12 months	CFW_Total	kg
Fibre diameter on 12 months wool	FD_Total	µm
6 months wool measurements		
CFW at February shearing	CFW_Feb	kg
CFW at August shearing	CFW_Aug	kg
FD at February shearing	FD_Feb	µm
FD at August shearing	FD_Aug	µm
Coefficient of variation of fibre diameter at February shearing	CV_Feb	%
Coefficient of variation of fibre diameter at August shearing	CV_Aug	%
Fibre curvature at February shearing	CUR_Feb	Degrees/mm
Fibre curvature at August shearing	CUR_Aug	Degrees/mm
Staple strength of February shorn staple (Agritester)	SS_Feb	N/ktex
Staple strength of August shorn staple (Agritester)	SS_Aug	N/ktex
Feb. and Aug. staple section measurements		
Clean wool growth	CWG1 to CWG7	% wool growth/day
Staple length wool growth	SLG1 to SLG7	mm/day
Fibre diameter	FD1 to FD7	µm
Coefficient of variation of fibre diameter	CV1 to CV7	%
Fibre curvature	CUR1 to CUR7	Degrees/mm

Table 2. Number of records, means and significance level of the fixed factors (*F*-values) fitted in the model for (i) total, 6 and 12 months wool measurements, (ii) clean wool growth sections (CWG), (iii) staple length wool growth (SLG), (iv) fibre diameter (FD), (v) coefficient of variation of fibre diameter (CV), and (vi) fibre curvature (CUR)

Trait	Unit	*N*	Mean	s.e.	Year of birth (BYR)	Age of dam (DA)	Stud (S)	Birth status (BS)	Interaction *F*-value	DOL
Total, 6 and 12 months wool measurements										
CFW Total	kg	2612	3.07	0.11	232.9***	12.1***	10.6***	57.2***	S × BYR*	n.s.
CFW_Feb	kg	2716	1.28	0.15	304.8***	12.6***	8.7***	84.9***	S × BYR***	4.24**
CFW_Aug	kg	2158	1.82	0.07	232.3***	10.8***	9.9***	20.9***	S × BYR*	n.s.
FD_Feb	µm	2732	20.2	0.85	76.8***	n.s.	21.5***	12.0***	n.s.	3.12**
FD_Aug	µm	2671	19.1	0.24	119.1***	3.3*	17.9***	11.9***	n.s.	n.s.
FD Tot	µm	2649	20.0	0.80	69.7***	n.s.	19.6***	13.1***	n.s.	2.65*
SS_Feb	N/ktex	1794	53.4	1.98	35.6***	n.s.	n.s.	n.s.	S × BYR*	n.s.
SS_Aug	N/ktex	1700	57.7	0.74	9.9***	n.s.	n.s.	n.s.	n.s.	n.s.
Clean wool growth sections (CWG)										
CWG1	%/day	2630	0.0050	0.0001	358.9***	3.1*	n.s.	n.s.	n.s.	n.s.
CWG2	%/day	2233	0.0013	0.0001	244.0***	4.7**	7.1***	n.s.	n.s.	n.s.
CWG3	%/day	2631	0.0021	0.0001	232.2***	12.2***	6.7***	n.s.	n.s.	4.19**
CWG4	%/day	2615	0.0028	0.0001	735.7***	7.5***	5.0***	n.s.	n.s.	n.s.
CWG5	%/day	1649	0.0031	0.0001	589.1***	12.4***	12.5***	n.s.	n.s.	n.s.
CWG6	%/day	1757	0.0030	0.0001	225.1***	n.s.	4.6***	n.s.	n.s.	n.s.
CWG7	%/day	2110	0.0028	0.0001	650.9***	12.7***	9.3***	n.s.	n.s.	n.s.
Staple length wool growth (SLG)										
SLG1	mm/day	2278	0.404	0.009	7.7***	7.1***	7.7***	n.s.	S × BS*	n.s.
SLG2	mm/day	2186	0.288	0.004	307.4***	4.1**	10.6***	n.s.	n.s.	n.s.
SLG3	mm/day	2583	0.299	0.005	2144.0***	36.1***	51.8***	4.3*	n.s.	n.s.
SLG4	mm/day	2561	0.360	0.005	114.6***	n.s.	6.4***	n.s.	n.s.	n.s.
SLG5	mm/day	1630	0.346	0.006	45.7***	2.7*	6.4***	n.s.	S × BS*	n.s.
SLG6	mm/day	1730	0.353	0.006	81.2***	n.s.	8.7***	n.s.	n.s.	n.s.
SLG7	mm/day	2091	0.380	0.006	192.9***	2.9*	3.4*	n.s.	n.s.	n.s.
Fibre diameter (FD)										
FD1	µm	2631	22.2	1.21	26.4***	n.s.	17.6***	4.3*	n.s.	2.73*
FD2	µm	2230	21.2	1.20	22.4***	n.s.	13.8***	n.s.	S × BS*	3.20*
FD3	µm	2621	19.5	1.14	67.8***	n.s.	15.1***	7.9***	S × BS*	3.71**
FD4	µm	2614	17.6	0.27	83.0***	n.s.	18.9***	6.8**	n.s.	n.s.
FD5	µm	1648	18.4	0.31	225.8***	6.3***	18.0***	3.2*	n.s.	n.s.
FD6	µm	1756	20.1	0.33	59.7***	3.6*	14.9***	5.0**	n.s.	n.s.
FD7	µm	2103	20.9	0.30	66.8***	2.4*	20.7***	n.s.	n.s.	n.s.
Coefficient of variation of fibre diameter (CV)										
CV1	%	2631	19.9	0.42	10.6***	n.s.	3.9*	29.5***	n.s.	n.s.
CV2	%	2230	20.1	0.53	17.9***	n.s.	2.8**	13.8***	n.s.	n.s.
CV3	%	2621	20.9	0.56	23.7***	n.s.	4.3***	9.1***	n.s.	n.s.
CV4	%	2614	20.5	0.58	29.4***	n.s.	3.6**	10.2***	S × BS*	n.s.
CV5	%	1648	20.6	0.60	41.3***	n.s.	4.3***	9.1***	n.s.	n.s.
CV6	%	1756	19.4	0.53	n.s.	n.s.	3.1**	10.2***	n.s.	n.s.
CV7	%	2103	18.9	0.48	18.3***	n.s.	4.3***	16.9***	n.s.	n.s.
Fibre curvature (CUR)										
CUR1	Degrees/mm	2631	81.4	1.31	56.8***	n.s.	18.0***	n.s.	n.s.	n.s.
CUR2	Degrees/mm	2230	84.9	1.64	32.4***	n.s.	16.2***	n.s.	n.s.	n.s.
CUR3	Degrees/mm	2621	82.2	1.69	20.6***	n.s.	17.3***	n.s.	n.s.	n.s.
CUR4	Degrees/mm	2614	92.1	2.83	54.7***	2.6*	15.1***	n.s.	DA × BYR*	n.s.
CUR5	Degrees/mm	1648	87.4	2.62	32.8***	n.s.	11.4***	n.s.	DA × BYR*	n.s.
CUR6	Degrees/mm	1756	79.5	1.53	23.8***	4.2**	20.9***	n.s.	n.s.	n.s.
CUR7	Degrees/mm	2103	78.4	2.21	24.3***	2.9*	25.3***	n.s.	S × BYR*	n.s.

*$P < 0.05$; **$P < 0.01$; ***$P < 0.001$; n.s., not significant ($P > 0.05$).

the total CFW is shown in Table 4. There was a clear pattern in that CWG1, CWG2 and CWG3 were in general positively correlated with each other, but negatively correlated with CWG4, CWG5, CWG6 and CWG7. The latter 4 traits were positively correlated with each other. The relationship between CWG1, CWG2 and CWG3 with CFW_Aug, CFW_Feb and CFW_Total was very weak and unclear. These correlations were generally very low and also in an opposite direction than in Table 3. However, CFW_Feb and CFW_Aug had a high environmental correlation with CFW_Total.

Table 5 indicates the phenotypic variation and environmental correlations between FD of the different sections at different times of the year.

The results show that the sections displayed significantly (*P*<0.01) more phenotypic variation for FD between animals than that of 6 months wool shorn in February and August or that of total FD.

The environmental correlations between FD of the different sections were all positive. Adjacent sections had higher environmental correlations than sections further apart. Moderately positive environmental correlations were

Table 3. Phenotypic variation (σ^2 ± s.e. on diagonal) of staple length growth (mm/day) of the different sections and the environmental correlation between staple length wool growth over different periods and with clean fleece weight

Variation of SLG1–SLG7 multiplied by 1000

	SLG1	SLG2	SLG3	SLG4	SLG5	SLG6	SLG7	CFW_Aug	CFW_Feb	CFW_Total
SLG1	4.5 ± 0.14	0.18 ± 0.03	0.12 ± 0.04	0.07 ± 0.04	0.14 ± 0.05	0.03 ± 0.05	0.01 ± 0.05	0.12 ± 0.05	0.11 ± 0.04	0.11 ± 0.04
SLG2		1.0 ± 0.03	0.20 ± 0.04	0.04 ± 0.04	0.08 ± 0.05	0.12 ± 0.05	0.10 ± 0.05	0.18 ± 0.05	0.18 ± 0.04	0.21 ± 0.05
SLG3			1.6 ± 0.05	0.02 ± 0.04	0.17 ± 0.05	0.03 ± 0.05	0.07 ± 0.06	0.08 ± 0.05	0.11 ± 0.04	0.10 ± 0.05
SLG4				2.2 ± 0.06	0.09 ± 0.05	0.07 ± 0.04	0.06 ± 0.04	0.10 ± 0.05	–0.02 ± 0.04	0.06 ± 0.04
SLG5					1.6 ± 0.06	0.30 ± 0.05	0.28 ± 0.05	0.13 ± 0.06	0.13 ± 0.05	0.14 ± 0.04
SLG6						1.6 ± 0.06	0.25 ± 0.05	0.16 ± 0.06	0.11 ± 0.05	0.19 ± 0.06
SLG7							2.2 ± 0.07	0.09 ± 0.05	0.04 ± 0.06	0.08 ± 0.05

Table 4. Phenotypic variation (σ^2 ± s.e. on diagonal) of clean wool growth (%/day) of the different sections, and the environmental correlation between clean fleece weight over different periods

Variation of CWG1–CWG7 multiplied by 100000

	CWG1	CWG2	CWG3	CWG4	CWG5	CWG6	CWG7	CFW_Aug	CFW_Feb	CFW_Total
CWG1	1.22 ± 0.04	0.27 ± 0.03	0.26 ± 0.03	–0.76 ± 0.01	–0.81 ± 0.02	–0.75 ± 0.02	–0.63 ± 0.02	0.05 ± 0.05	0.13 ± 0.04	0.10 ± 0.04
CWG2		0.21 ± 0.01	0.93 ± 0.01	–0.49 ± 0.03	–0.36 ± 0.04	–0.43 ± 0.03	–0.30 ± 0.04	–0.02 ± 0.05	0.00 ± 0.05	–0.01 ± 0.05
CWG3			0.41 ± 0.01	–0.49 ± 0.03	–0.44 ± 0.03	–0.39 ± 0.03	–0.35 ± 0.03	–0.03 ± 0.05	–0.01 ± 0.04	–0.02 ± 0.04
CWG4				0.36 ± 0.01	0.58 ± 0.03	0.61 ± 0.03	0.39 ± 0.03	–0.05 ± 0.04	–0.09 ± 0.04	–0.09 ± 0.04
CWG5					0.39 ± 0.01	0.50 ± 0.04	0.50 ± 0.03	0.01 ± 0.05	–0.11 ± 0.05	–0.08 ± 0.05
CWG6						0.39 ± 0.01	0.41 ± 0.04	–0.10 ± 0.06	–0.10 ± 0.05	–0.09 ± 0.05
CWG7							0.46 ± 0.01	–0.01 ± 0.05	–0.10 ± 0.05	–0.07 ± 0.05
CFW_Aug								0.10 ± 0.003	0.34 ± 0.04	0.80 ± 0.02
CFW_Feb									0.06 ± 0.002	0.78 ± 0.02
CFW_Total										0.24 ± 0.007

Table 5. Phenotypic variation (σ^2 ± s.e. on diagonal) of fibre diameter (μm) of the different sections and the environmental correlation of fibre diameter measured over different periods

	FD1	FD2	FD3	FD4	FD5	FD6	FD7	FD_Aug	FD_Feb	FD_Total
FD1	3.42 ± 0.11	0.63 ± 0.04	0.55 ± 0.05	0.25 ± 0.06	0.21 ± 0.08	0.24 ± 0.07	0.27 ± 0.07	0.33 ± 0.07	0.55 ± 0.04	0.51 ± 0.06
FD2		3.23 ± 0.11	0.74 ± 0.03	0.32 ± 0.06	0.21 ± 0.07	0.24 ± 0.07	0.26 ± 0.07	0.38 ± 0.07	0.56 ± 0.04	0.53 ± 0.05
FD3			2.99 ± 0.09	0.42 ± 0.05	0.37 ± 0.06	0.29 ± 0.07	0.32 ± 0.06	0.42 ± 0.06	0.47 ± 0.05	0.51 ± 0.05
FD4				3.40 ± 0.10	0.76 ± 0.03	0.68 ± 0.04	0.56 ± 0.04	0.48 ± 0.05	0.30 ± 0.06	0.46 ± 0.06
FD5					3.52 ± 0.13	0.72 ± 0.04	0.71 ± 0.03	0.46 ± 0.06	0.32 ± 0.06	0.42 ± 0.07
FD6						3.68 ± 0.13	0.76 ± 0.03	0.48 ± 0.06	0.30 ± 0.06	0.47 ± 0.07
FD7							3.55 ± 0.12	0.49 ± 0.06	0.29 ± 0.06	0.40 ± 0.08
FD_Aug								2.47 ± 0.08	0.46 ± 0.06	0.99 ± 0.00
FD_Feb									2.28 ± 0.07	0.84 ± 0.02
FD_Total										2.14 ± 0.07

Table 6. Phenotypic variation (σ^2 ± s.e. on diagonal) of coefficient of variation of fibre diameter (%) of the sections and of staple strength (N/ktex) measured on 6 months wool growth and the environmental correlation between coefficient of variation of fibre diameter of the different staple sections and of staple strength measured on 6 months wool staples from August and February shearing

	CV1	CV2	CV3	CV4	CV5	CV6	CV7	SS_Aug	SS_Feb
CV1	8.04 ± 0.26	0.63 ± 0.03	0.61 ± 0.04	0.27 ± 0.06	0.21 ± 0.07	0.18 ± 0.08	0.28 ± 0.06	0.04 ± 0.07	0.04 ± 0.06
CV2		11.68 ± 0.38	0.74 ± 0.03	0.28 ± 0.07	0.22 ± 0.08	0.22 ± 0.09	0.32 ± 0.06	0.07 ± 0.08	0.09 ± 0.07
CV3			13.25 ± 0.42	0.30 ± 0.06	0.24 ± 0.07	0.27 ± 0.07	0.30 ± 0.06	0.04 ± 0.08	0.04 ± 0.07
CV4				13.62 ± 0.42	0.71 ± 0.03	0.64 ± 0.04	0.59 ± 0.04	–0.05 ± 0.07	0.01 ± 0.06
CV5					12.58 ± 0.50	0.66 ± 0.04	0.69 ± 0.04	–0.06 ± 0.09	0.16 ± 0.08
CV6						11.03 ± 0.43	0.72 ± 0.04	–0.35 ± 0.08	0.13 ± 0.08
CV7							9.17 ± 0.32	–0.04 ± 0.08	0.05 ± 0.07
SS_Aug								170 ± 6.20	0.28 ± 0.02
SS_Feb									101 ± 3.50

found between the section FD and FD_Feb, FD_Aug and FD_Total. The environmental correlation between FD_Feb and FD_Aug was also moderately positive, and very high correlations were found between FD_Aug and FD_Total and between FD_Feb and FD_Total.

The phenotypic variation of CV increases from CV1 (after weaner shearing) up to CV4 after which it declined again (Table 6). Moderate to high environmental variation was estimated with the highest correlation between adjacent sections. The environmental correlation between CV1 to CV7 with SS in February (SS_Feb) was generally positive, while SS in August (SS_Aug) was negatively correlated with CV4, CV5, CV6 and CV7.

Fibre curvature (Table 7) also showed an increase in phenotypic variation from CUR1 that reached a peak at 130 (degrees/mm)^2 for CUR3, after which it declined again to 75 (degrees/mm)^2. The environmental correlations were moderately high with higher correlations between adjacent sections that decrease as the sections are further apart.

Genetic parameters

The heritability estimates of staple length wool growth are given in Table 8. SLG1 had a low heritability of 0.10 whereas the heritability of the other sections was more than twice this estimate. But the heritability estimates of CFW_Feb, CFW_Aug and CFW_Total was again about twice that of the sections. The phenotypic correlations between SLG of the different sections were in general moderate to moderately low which decreased as the sections became further apart.

Moderate heritability estimates were obtained for CFW_Feb and CFW_Aug with the heritability of CFW_Feb slightly lower than CFW_Aug. The genetic correlations between staple length wool growth of the different sections were generally positive and varied from moderate to 1 (between SLG2 and SLG5). No clear trend was apparent. However, the genetic relationship between SLG of the sections and CFW_Feb, CFW_Aug and CFW_Total varied from negative (–0.02 between SLG3 and CFW_Feb, and –0.04 between CWG6 and CFW_Feb) to 0.72 (between SLG1 and CFW_Feb). High genetic correlations (r_g >0.9) were found between CFW_Feb and CFW_Total and between CFW_Aug and CFW_Total. However, a low phenotypic correlation of 0.52 was found between CFW_Feb and CFW_Aug while the genetic correlation between these 2 traits was 0.78.

The heritability of CWG of the 7 sections were reasonably similar but much lower than that for SLG indicating a high environmental component to this trait (Table 9). The phenotypic and genetic correlations between CWG of the sections were highly variable and varied from highly negative to strongly positive. The genetic correlation between CWG of the different sections with CFW_Feb, CFW_Aug or CFW_Total varied from zero to 0.57 (CWG5 and CFW_Aug). CWG1, CWG2 and CWG3 in particular

Table 7. Phenotypic variation (σ^2 ± s.e. on diagonal) of fibre curvature (degrees/mm) and the environmental correlation between fibre curvature of the staple section measured over different periods

	CUR1	CUR2	CUR3	CUR4	CUR5	CUR6	CUR7
CUR1	91.6 ± 2.75	0.61 ± 0.03	0.56 ± 0.04	0.22 ± 0.05	0.27 ± 0.06	0.27 ± 0.06	0.29 ± 0.05
CUR2		119.8 ± 3.84	0.74 ± 0.03	0.32 ± 0.05	0.25 ± 0.07	0.31 ± 0.06	0.30 ± 0.06
CUR3			130.5 ± 4.16	0.28 ± 0.05	0.23 ± 0.07	0.29 ± 0.06	0.31 ± 0.06
CUR4				122.9 ± 3.79	0.70 ± 0.03	0.60 ± 0.04	0.59 ± 0.04
CUR5					99.3 ± 3.75	0.68 ± 0.04	0.69 ± 0.04
CUR6						89.3 ± 3.33	0.74 ± 0.03
CUR7							75.1 ± 2.60

Table 8. **Heritability estimates (on diagonal) of staple length growth of the sections, and the phenotypic (above diagonal) and genetic (below diagonal) correlations between staple length wool growth of the different staple sections and with clean fleece weight of 6 and 12 months wool growth**

	SLG1	SLG2	SLG3	SLG4	SLG5	SLG6	SLG7	CFW_Aug	CFW_Feb	CFW_Total
SLG1	**0.10 ± 0.04**	0.20 ± 0.02	0.17 ± 0.02	0.19 ± 0.02	0.22 ± 0.03	0.11 ± 0.04	0.11 ± 0.04	0.18 ± 0.02	0.22 ± 0.02	0.22 ± 0.02
SLG2	0.33 ± 0.19	**0.23 ± 0.04**	0.38 ± 0.02	0.20 ± 0.02	0.34 ± 0.02	0.31 ± 0.05	0.28 ± 0.02	0.21 ± 0.03	0.13 ± 0.02	0.20 ± 0.02
SLG3	0.42 ± 0.18	0.92 ± 0.09	**0.24 ± 0.04**	0.20 ± 0.02	0.33 ± 0.02	0.28 ± 0.02	0.26 ± 0.02	0.16 ± 0.02	0.07 ± 0.02	0.14 ± 0.02
SLG4	0.94 ± 0.20	0.76 ± 0.13	0.78 ± 0.11	**0.21 ± 0.04**	0.26 ± 0.02	0.28 ± 0.02	0.25 ± 0.03	0.26 ± 0.02	0.13 ± 0.02	0.22 ± 0.02
SLG5	0.67 ± 0.21	1.03 ± 0.10	0.77 ± 0.11	0.82 ± 0.13	**0.26 ± 0.04**	0.43 ± 0.03	0.42 ± 0.02	0.31 ± 0.02	0.17 ± 0.03	0.28 ± 0.02
SLG6	0.48 ± 0.20	0.81 ± 0.11	0.95 ± 0.11	0.95 ± 0.12	0.76 ± 0.14	**0.29 ± 0.06**	0.37 ± 0.02	0.27 ± 0.03	0.06 ± 0.03	0.19 ± 0.03
SLG7	0.71 ± 0.23	0.88 ± 0.12	0.83 ± 0.11	0.97 ± 0.12	0.89 ± 0.10	0.74 ± 0.13	**0.20 ± 0.05**	0.20 ± 0.02	0.06 ± 0.02	0.16 ± 0.02
CFW_Aug	0.44 ± 0.16	0.30 ± 0.12	0.34 ± 0.10	0.63 ± 0.10	0.63 ± 0.08	0.47 ± 0.11	0.45 ± 0.12	**0.45 ± 0.05**	0.52 ± 0.02	0.87 ± 0.01
CFW_Feb	0.72 ± 0.16	0.02 ± 0.12	–0.02 ± 0.11	0.48 ± 0.11	0.39 ± 0.12	–0.04 ± 0.12	0.14 ± 0.13	0.78 ± 0.05	**0.39 ± 0.04**	0.83 ± 0.01
CFW_Total	0.65 ± 0.15	0.20 ± 0.10	0.22 ± 0.09	0.62 ± 0.10	0.56 ± 0.10	0.21 ± 0.11	0.34 ± 0.12	0.95 ± 0.01	0.92 ± 0.02	**0.46 ± 0.05**

had low genetic correlations with CFW_Feb, CFW_Aug and also with CFW_Total.

Heritability estimates of FD of the different sections during different times of the year (Table 10) were high. However, the heritability of FD_Aug and FD_Total was significantly ($P<0.01$) higher than FD_Feb as tested using their standard errors. The phenotypic correlations between FD of the sections were generally high, higher between adjacent sections and declined as the sections were further apart. The genetic correlation between FD of the sections with FD_Feb, FD_Aug and FD_Total was in general high ($r_g > 0.85$).

CV of the different sections (CV1 to CV7) had relatively high heritability estimates. High phenotypic correlations ($r_p > 0.60$) and very high genetic correlations ($r_g > 0.92$). were found between CV of the different sections.

The genetic correlations between CV of the different sections with SS_Feb and SS_Aug are shown in Table 11. SS was shown to have a low negative phenotypic correlation with CV and a moderate negative genetic correlation with CV.

Table 12 shows that CUR, measured any time of the year, is moderately highly heritable. Curvature of the different sections is also phenotypically highly correlated with each other but the relationship is higher between adjacent sections.

Discussion

Environmental factors

Clean and staple length growth followed a reasonably similar pattern (Fig. 2) except that SLG6 and SLG7 showed an increase while CWG6 and CWG7 decreased. This pattern is not exactly similar to the FD profile which indicates that FD and weight of wool grown during the year is out of phase. Schlink *et al*. (1999) found that the FD:fibre length ratio of Merino sheep was not constant across seasons under grazing conditions, while a number of studies of penned sheep have found a constant ratio. It is highly

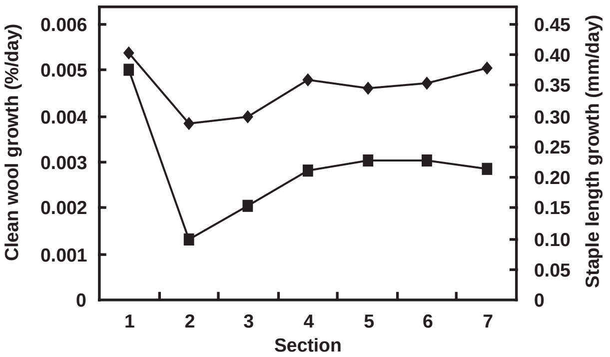

Figure 2. Clean (■, %/day) and staple length (◆, mm/day) wool growth of the different sections during the year.

Table 9. **Heritability estimates (on diagonal) of clean wool growth of the sections and the phenotypic (above diagonal) and genetic (below diagonal) correlations between clean wool growth of the different staple sections and with clean fleece weight of 6 and 12 months wool growth**

	CWG1	CWG2	CWG3	CWG4	CWG5	CWG6	CWG7	CFW_Aug	CFW_Feb	CFW_Total
CWG1	**0.11 ± 0.04**	0.14 ± 0.02	0.16 ± 0.02	–0.76 ± 0.01	–0.77 ± 0.01	–0.72 ± 0.01	–0.63 ± 0.01	0.01 ± 0.02	0.15 ± 0.02	0.07 ± 0.02
CWG2	–0.91 ± 0.32	**0.09 ± 0.05**	0.93 ± 0.01	–0.40 ± 0.02	–0.33 ± 0.02	–0.36 ± 0.02	–0.27 ± 0.02	–0.03 ± 0.03	–0.02 ± 0.02	–0.02 ± 0.02
CWG3	–0.71 ± 0.31	0.94 ± 0.04	**0.10 ± 0.04**	–0.40 ± 0.02	–0.43 ± 0.02	–0.34 ± 0.02	–0.34 ± 0.02	–0.04 ± 0.02	–0.04 ± 0.02	–0.04 ± 0.02
CWG4	–0.84 ± 0.13	0.87 ± 0.63	0.66 ± 0.57	**0.04 ± 0.03**	0.55 ± 0.02	0.59 ± 0.02	0.38 ± 0.02	–0.06 ± 0.02	–0.11 ± 0.02	–0.08 ± 0.02
CWG5	–0.34 ± 0.25	–0.00 ± 0.39	–0.36 ± 0.33	0.12 ± 0.44	**0.09 ± 0.05**	0.48 ± 0.03	0.46 ± 0.02	0.07 ± 0.03	–0.06 ± 0.03	0.01 ± 0.03
CWG6	–0.45 ± 0.26	0.69 ± 0.88	0.46 ± 0.76	0.21 ± 0.58	0.22 ± 0.49	**0.02 ± 0.05**	0.43 ± 0.02	–0.02 ± 0.03	–0.10 ± 0.03	–0.03 ± 0.02
CWG7	–0.57 ± 0.19	0.15 ± 0.44	–0.17 ± 0.33	0.29 ± 0.44	–0.13 ± 0.58	0.96 ± 0.61	**0.06 ± 0.04**	0.01 ± 0.02	–0.08 ± 0.02	–0.03 ± 0.02
CFW_Aug	–0.11 ± 0.16	–0.06 ± 0.18	–0.07 ± 0.16	–0.17 ± 0.23	0.29 ± 0.22	0.64 ± 0.79	0.09 ± 0.21		Estimates	
CFW_Feb	0.28 ± 0.15	–0.13 ± 0.15	–0.14 ± 0.16	–0.32 ± 0.23	0.07 ± 0.22	–0.24 ± 0.37	–0.01 ± 0.21		In	
CFW_Total	0.13 ± 0.13	–0.02 ± 0.15	0.07 ± 0.15	0.41 ± 0.13	0.45 ± 0.12	0.41 ± 0.08	0.49 ± 0.27		Table 8	

Table 10. Heritability estimates (on diagonal) of fibre diameter of the sections, and the phenotypic (above diagonal) and genetic (below diagonal) correlations between fibre diameter of the different staple sections and with fibre diameter of 6 and 12 months wool growth

	FD1	FD2	FD3	FD4	FD5	FD6	FD7	FD_Aug	FD_Feb	FD_Total
FD1	**0.65 ± 0.04**	0.82 ± 0.01	0.77 ± 0.01	0.64 ± 0.01	0.62 ± 0.02	0.63 ± 0.02	0.64 ± 0.01	0.75 ± 0.01	0.82 ± 0.01	0.82 ± 0.01
FD2	0.92 ± 0.01	**0.62 ± 0.04**	0.89 ± 0.01	0.69 ± 0.01	0.62 ± 0.02	0.64 ± 0.01	0.62 ± 0.02	0.75 ± 0.01	0.78 ± 0.01	0.81 ± 0.01
FD3	0.90 ± 0.02	0.99 ± 0.01	**0.60 ± 0.04**	0.73 ± 0.01	0.67 ± 0.01	0.64 ± 0.01	0.63 ± 0.01	0.75 ± 0.01	0.73 ± 0.01	0.78 ± 0.01
FD4	0.89 ± 0.02	0.94 ± 0.02	0.94 ± 0.02	**0.56 ± 0.04**	0.86 ± 0.01	0.81 ± 0.01	0.76 ± 0.01	0.78 ± 0.01	0.65 ± 0.01	0.76 ± 0.01
FD5	0.90 ± 0.03	0.95 ± 0.04	0.90 ± 0.03	0.94 ± 0.01	**0.53 ± 0.06**	0.83 ± 0.01	0.83 ± 0.01	0.77 ± 0.01	0.62 ± 0.01	0.75 ± 0.01
FD6	0.86 ± 0.03	0.88 ± 0.03	0.85 ± 0.04	0.91 ± 0.02	0.93 ± 0.03	**0.60 ± 0.05**	0.88 ± 0.01	0.78 ± 0.01	0.65 ± 0.01	0.77 ± 0.01
FD7	0.86 ± 0.03	0.87 ± 0.04	0.85 ± 0.03	0.91 ± 0.03	0.92 ± 0.02	0.97 ± 0.01	**0.59 ± 0.06**	0.79 ± 0.01	0.66 ± 0.02	0.74 ± 0.01
FD_Aug	0.93 ± 0.02	0.94 ± 0.02	0.92 ± 0.02	0.95 ± 0.01	0.96 ± 0.02	0.93 ± 0.01	0.94 ± 0.02	**0.75 ± 0.04**	0.79 ± 0.01	0.96 ± 0.00
FD_Feb	0.98 ± 0.01	0.94 ± 0.02	0.91 ± 0.02	0.90 ± 0.02	0.87 ± 0.03	0.94 ± 0.03	0.92 ± 0.04	0.94 ± 0.01	**0.60 ± 0.04**	0.93 ± 0.01
FD_Total	0.96 ± 0.01	0.95 ± 0.01	0.93 ± 0.01	0.94 ± 0.06	0.95 ± 0.06	0.92 ± 0.02	0.94 ± 0.03	0.99 ± 0.01	0.98 ± 0.01	**0.76 ± 0.04**

likely that the fibre length:FD ratio could have been different in this study. The interactions between FD and SLG may explain this trend of why the FD profile did not follow the CWG profile.

A sharp decrease in CWG and SLG occurred from the first to the second staple section. This may have been caused by a lack of adequate feeding during this time as the normal feeding protocol during this experiment was to start from the second week of January.

Phenotypic variation and environmental correlations

The generally positive environmental correlations (Table 3) between SLG implies that positive environmental effects on SLG at any time of the year will have a very small positive effect on SLG at other times and over the total wool growth period.

The pattern in Table 4 shows that CWG1, CWG2 and CWG3 were in general positively correlated, but negatively correlated with CWG4, CWG5, CWG6 and CWG7. The latter 4 traits were positively correlated with each other. This pattern indicates that there may be confounding issues involved because CWG1, CWG2 and CWG3 are from the 6 month wool staple produced from weaning to February, while CWG4, CWG5, CWG6 and CWG7 originated from the subsequent 6 months wool staple shorn in August.

Table 5 shows an interesting phenomenon in that FD of the sections had significantly (P<0.01) more phenotypic variation than FD of the 6 months wool growth shorn in February and August, or that of wool grown over 12 months

Table 11. Heritability estimates (on diagonal) of coefficient of variation of fibre diameter of the different sections, and the phenotypic (above diagonal) and genetic (below diagonal) correlations between coefficient of variation of fibre diameter of the different staple sections with staple strength measured on 6 months wool growth shorn in August and February

	CV1	CV2	CV3	CV4	CV5	CV6	CV7	SS_Aug	SS_Feb
CV1	**0.59 ± 0.04**	0.84 ± 0.01	0.82 ± 0.01	0.65 ± 0.01	0.61 ± 0.02	0.65 ± 0.01	0.68 ± 0.02	–0.16 ± 0.03	–0.15 ± 0.02
CV2	0.98 ± 0.01	**0.62 ± 0.04**	0.89 ± 0.01	0.71 ± 0.01	0.65 ± 0.02	0.71 ± 0.01	0.65 ± 0.01	–0.21 ± 0.03	–0.13 ± 0.03
CV3	0.95 ± 0.01	0.99 ± 0.01	**0.65 ± 0.04**	0.73 ± 0.01	0.67 ± 0.01	0.72 ± 0.01	0.69 ± 0.01	–0.21 ± 0.03	–0.14 ± 0.02
CV4	0.93 ± 0.02	0.98 ± 0.01	1.00 ± 0.01	**0.59 ± 0.04**	0.85 ± 0.01	0.84 ± 0.01	0.80 ± 0.01	–0.22 ± 0.02	–0.15 ± 0.03
CV5	0.92 ± 0.04	0.96 ± 0.02	0.99 ± 0.03	0.95 ± 0.01	**0.55 ± 0.04**	0.85 ± 0.01	0.84 ± 0.01	–0.22 ± 0.03	–0.12 ± 0.03
CV6	0.96 ± 0.02	0.98 ± 0.02	0.99 ± 0.02	0.99 ± 0.01	0.98 ± 0.02	**0.60 ± 0.06**	0.88 ± 0.01	–0.39 ± 0.03	–0.18 ± 0.15
CV7	0.96 ± 0.04	0.94 ± 0.03	0.95 ± 0.02	0.94 ± 0.02	0.96 ± 0.02	0.99 ± 0.01	**0.57 ± 0.08**	–0.18 ± 0.03	–0.12 ± 0.03
SS_Aug	–0.40 ± 0.09	–0.53 ± 0.09	–0.47 ± 0.09	–0.44 ± 0.09	–0.43 ± 0.09	–0.46 ± 0.11	–0.37 ± 0.10	**0.33 ± 0.06**	0.28 ± 0.02
SS_Feb	–0.52 ± 0.12	–0.53 ± 0.12	–0.46 ± 0.12	–0.45 ± 0.12	–0.67 ± 0.15	–0.30 ± 0.15	–0.49 ± 0.14	0.87 ± 0.12	**0.20 ± 0.05**

Table 12. Heritability estimates (on diagonal) of fibre curvature of the sections, and the phenotypic (above diagonal) and genetic (below diagonal) correlations between fibre curvature of the different staple sections

	CUR1	CUR2	CUR3	CUR4	CUR5	CUR6	CUR7
CUR1	**0.43 ± 0.05**	0.76 ± 0.01	0.73 ± 0.01	0.52 ± 0.02	0.56 ± 0.01	0.58 ± 0.02	0.58 ± 0.02
CUR2	0.93 ± 0.02	**0.52 ± 0.05**	0.87 ± 0.01	0.59 ± 0.01	0.59 ± 0.02	0.61 ± 0.02	0.60 ± 0.02
CUR3	0.90 ± 0.03	0.98 ± 0.01	**0.58 ± 0.05**	0.60 ± 0.01	0.59 ± 0.02	0.62 ± 0.02	0.60 ± 0.02
CUR4	0.87 ± 0.04	0.88 ± 0.04	0.92 ± 0.03	**0.45 ± 0.04**	0.80 ± 0.01	0.76 ± 0.01	0.73 ± 0.01
CUR5	0.88 ± 0.05	0.91 ± 0.05	0.88 ± 0.04	0.91 ± 0.02	**0.54 ± 0.04**	0.84 ± 0.01	0.82 ± 0.01
CUR6	0.92 ± 0.04	0.87 ± 0.04	0.88 ± 0.04	0.93 ± 0.02	0.98 ± 0.01	**0.53 ± 0.06**	0.88 ± 0.01
CUR7	0.89 ± 0.04	0.84 ± 0.06	0.87 ± 0.04	0.85 ± 0.04	0.94 ± 0.03	0.98 ± 0.02	**0.55 ± 0.08**

which was a weighted average of the February and August average FD. The standard errors of the phenotypic variation of FD of the sections were about twice that of the phenotypic variation of FD on wool grown over 6 or 12 months that shows the higher sampling or measurement error of the smaller samples. However, the sections displayed significantly ($P<0.01$) more phenotypic variation between animals for FD relative to that of wool grown over 6 months. The underlying reasons for this is unclear and more work needs to be done to elucidate this issue.

Table 6 shows that the phenotypic variation of CV increases from CV1 after weaner shearing up to CV4 after which it declined again. This followed a seasonal pattern with the higher variation coinciding with the dry summer and autumn periods. Similarly variation between sheep for fibre curvature (Table 7) also followed a seasonal pattern but reached a peak at CUR3, after which it declined again.

Genetic parameters

The low heritability estimates of SLG (Table 8) and the even lower estimates of CWG (Table 9) relative to that of CFW_Aug, CFW_Feb and CFW_Total, indicate the low accuracy of using these part records measurements as indicator traits to identify genetically superior animals for fleece weight. Heritability of CFW_Feb was slightly lower than CFW_Aug but not different from the generally accepted heritability estimates published in the literature (Mortimer 1987).

The genetic correlations between staple length wool growth of the different sections were generally positive and varied from moderate to 1 but no clear trend was apparent. Similarly, no clear trend could be seen between SLG of the sections and CFW_Feb, CFW_Aug and CFW_Total, except that the genetic correlations of SLG of the sections were much more variable with CFW_Feb than with CFW_Aug.

Wheeler *et al*. (1977) and Briegel *et al*. (1998) also found a poor phenotypic relationship between SLG and CWG and both concluded that SLG was too variable to be used to estimate wool production rate. In this study the higher correlations between the SLG sections, and their higher heritability estimates as compared to CWG, indicate that SLG has a lower environmental error component. It therefore appears to be more accurate than CWG as measured by weighing staple sections. The higher genetic correlation between CFW grown over at least 6 months is a more accurate measurement.

The high genetic correlation found between CFW_Feb and CFW_Total and between CFW_Aug and CFW_Total is probable due to the fact that CFW_Aug and CFW_Feb are part of CFW_Total. The high genetic correlation of 0.78 between CFW_Aug and CFW_Feb indicates that these traits are suitable to be used to improve fleece weight. However, the low phenotypic correlation of 0.52, which supports the repeatability estimates of CFW in the literature (Mortimer 1987) generally supports general breeders' perception that fleece weights are not highly repeatable.

Heritability estimates of FD of the different sections during different times of the year (Table 10) were high and agreed very well with accepted published estimates (Mortimer 1987). In addition, high phenotypic and genetic relationships were found between sections, and between section FD_Aug and FD_Feb ($r_g > 0.85$). This implies that only a small reduction in efficiency of selection for FD will occur by using FD tested on short staples, and virtually no loss where wool staples grown over 6 months are used as compared to using FD measured on wool staples grown over 12 months.

CV of the different sections also had relatively high heritability estimates that agree well with published estimates in the literature (Greeff *et al*. 1995). This as well as the high phenotypic correlations ($r_p > 0.60$) and very high genetic correlations ($r_g > 0.92$) that were found between CV of the different sections, indicates that the same genes affect CV during the year.

The negative phenotypic and genetic correlations between CV of the different sections with SS_Feb and SS_Aug are very similar to those reported by Greeff *et al*. (1995). This again confirms that CV is a good and inexpensive indirect selection criterion to improve SS provided it has been measured on wool sampled from the same body site and on wool grown over the same time of the year.

A new finding from this study is the high genetic correlation between SS_Feb and SS_Aug ($r_g = 0.87 \pm 0.12$) that was not significantly different from unity. This indicates that largely the same genes that affect SS in one season also affect SS in another season. This is an important finding as there is a perception that SS measured on a wool staple grown over 6 months may not be genetically the same trait as SS from a wool staple grown over 12 months. The low phenotypic correlation of 0.28 ± 0.02 between SS_Feb and SS_Aug found in this study supports this belief. The large difference between the genetic and phenotypic correlations indicates that environmental factors play a very strong role in determining SS. But the high genetic correlation between SS_Feb and SS_Aug indicates that selection for SS on a wool staple grown over 6 months will also result in a correlated improvement in SS of the subsequent 6 months wool growth. Hence this will increase SS of wool grown over a 12 month growth period.

CUR of the different sections are moderately highly heritable (Table 12) and therefore should respond to selection. These estimates are higher than the 0.37 estimate published by Hatcher and Atkins (2000). Curvature of the sections is phenotypically highly correlated with each other and the relationship is higher between adjacent sections. The genetic correlations were also very high ($r_g > 0.84$) which indicates that the same genes that affect CUR at one point in time in a growing season, also affect it at another time of that growing season.

Conclusions

The positive environmental correlations between different sections for the same traits, imply that wool growth, FD, coefficient of variation of FD and CUR will increase if the environment improves. This supports the belief that these traits can be manipulated by management in a desirable direction.

The heritability estimates of FD, coefficient of variation of FD and CUR measured on short staples were similar to that of published estimates on wool grown over 12 months. In addition, the high genetic correlations between the fibre traits (FD, CV and CUR) of the different dyebanded sections and their 12-month counterpart, indicate that part records should be effective as an indirect selection criterion to improve these traits in Merino sheep. For FD, part records appear to be more effective than FD on wool grown over a full 12 months because of the higher phenotypic variation associated with part records than with full records, in spite of the fact that the heritability of FD of wool grown over 12 months was higher. However, using short periods of CWG or greasy SLG (short staples) will be very ineffective as an indirect selection criterion to improve CFW mainly because of their low heritabilities and low genetic correlation with total fleece weight grown over 12 months. The lower heritability estimates of these short-term wool growth measurements relative to 6 or 12 months of wool growth, indicates that these measurements have high errors associated with them. This implies that short-term wool growth as measured by either SLG or section weight, is not suitable to be used as an indirect selection criterion to increase total CFW.

The low phenotypic correlation of 0.52 between CFW_Feb and CFW_Aug compares very well with published repeatability estimates of fleece weights (Turner and Young 1969). The genetic correlation of 0.78 ± 0.02 between CFW_Feb and CFW_Aug shows that although there is a loss in efficiency, this relationship is strongly positive. This implies that selection for CFW_Feb will also result in genetic progress in CFW_Aug (and *vice versa*). Similarly for SS and FD because of the high genetic correlation between SS_Feb and SS_Aug (0.87 ± 0.12) and between FD_Feb and FD_Aug (0.94 ± 0.01). Therefore selection for CFW, FD or SS on 6 months wool, will result in an improvement in these traits on wool growth over the subsequent 6 months and thus also improve total CFW grown over 12 months.

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