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# Is Fibre Diameter Variation Along the Staple a Good Indirect Selection Criterion for Staple Strength?

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## Summary

The coefficient of variation of fibre diameter (CVFD) within the mid-side fleece sample is currently used to predict staple strength (SS) in Merino sheep (4.5 year old ewes). CVFD measures fibre diameter variation both between fibres and along wool fibres. It has been suggested that selection to improve staple strength should concentrate on reducing fibre diameter variation along the staple, rather than CVFD. Our results indicate that measurements of fibre diameter variability along the staple had low heritabilities to moderate (0.01 to 0.20) and a low to moderate (0.15 to -0.43) phenotypic correlation with staple strength. In comparison, CVFD was highly heritable (0.78) and had a moderate (-0.44) phenotypic correlation with SS. This suggests that there would be no advantage in using measures of fibre diameter variability along the staple as an indirect selection criterion for SS compared with the information provided by CVFD measured in a mid-side fleece sample.

**Keywords:** Staple strength, coefficient of variation, fibre diameter, heritability, correlations.

## Introduction

Staple strength is an important economic character in the wool industry, as it affects processing properties such as carding, combing losses and spinning breakage (Rottenbury et al. 1986; Whiteley 1987). Staple strength has a moderate to high heritability (0.23 to 0.51) which should enable genetic progress provided a suitable selection criterion can be found (Greeff 1997; Hill and Ponzoni 1999). To avoid the cost of staple strength measurement, attempts have been made to find an inexpensive indirect selection criterion.

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Coefficient of variation of fibre diameter (CVFD) is measured simultaneously with fibre diameter on a minicored mid-side sample. CVFD reflects the variation both between and along wool staples and has been identified as a potential indicator for staple strength (Greeff et al. 1995). Given the relationship between minimum fibre diameter and SS and between rate of diameter change and SS (Hansford and Kennedy 1990), we surmised that along fibre diameter variation could be the component of CVFD contributing to the relationship between CVFD and SS. In this paper we present phenotypic correlations and heritabilities for measures of variability in fibre diameter along the fibre. We also compare the merits of these measures as predictor of staple strength with that of coefficient variation of fibre diameter measured in mid-side samples.

## Materials and methods

### *Location and Sheep*

A resource flock of 2000 South Australian Merino strain ewes representative of the Bungaree and Collinsville family groups was established at the Turretfield Research Centre (South Australian Research and Development Institute) in 1988 (Ponzoni et al. 1995). The results presented in this paper are from 650 ewe progeny of this flock, born in 1992 and offspring of 47 sires.

### *Measurements*

The wool samples used in this study were taken from the mid-side of each fleece during the September 1996 shearing when the ewes were aged 4.5 years and had 12 months wool.

a. Mid-side sample
The mid-side wool samples (approximately 50g) were used to measure average fibre diameter (FD), coefficient of variation of fibre diameter (CVFD) and staple strength (SS) (about 4g of 15 wool staples) (Table 1). FD and CVFD were measured using the Fibre Finess Distribution Analyser (FFDA) (Information Electronic Limited under the licence from CSIRO). Staple strength was measured on 15 staples per mid-side by using the CSIRO-developed ATLAS (Automatic Testing of Length and Strength) instrument at Australian Wool Testing Authority (AWTA).

b. Along the staple
A staple was taken at random from each mid-side wool sample, and 10 snippets (2 mm in length) were cut out from equidistant points along the staple using a snippet profiler (CSIRO Textile and Fibre Technology, Geelong, Victoria). The remaining pieces of wool between the snippets (Figure 1), as well as the extremities (the tip and the base of the staple) were discarded. Each bundle of snippets (numbers 1 to 10) corresponds to approximately 10 different times of the year and with the wool samples were from


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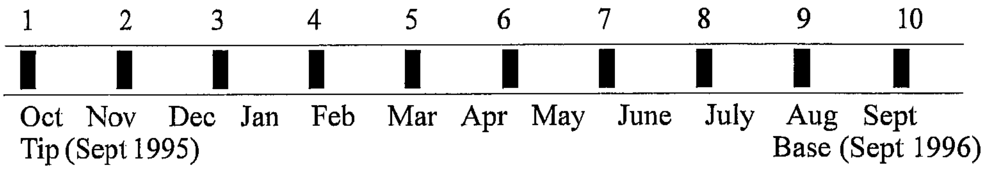
12 months of wool growth (shorn in September 1996, at the base, Figure 1). The snippets were washed with tetrachloroethylene and dried with a snippet blaster, the fibre diameter of 1000 wool fibres in each snippet was then measured using a Sirolan Laserscan (CSIRO Textile and Fibre Technology, Geelong, Victoria). The use of Sirolan Laserscan allows the measurement of the small snippet sample used in this study.

**Fig. 1 Diagram of the location of each snippet (1-10) (approximately) within one year's wool growth**




The fibre diameter measurements for each snippet were used to measure the along staple traits outlined in Table 1. Adjacent difference (ADJDIFF) was calculated as the sum of the squared difference between adjacent fibre diameter measurements along the staple, divided by the number of snippets along the staple minus one. Rate of FD change (RATE) was calculated as the difference between FDMAX and FDMIN, divided by the difference between the corresponding snippet numbers at which FDMAX and FDMIN occurred.

**Table 1. Traits measured in mid-side sample and along the staple**

| Trait | Abbreviation | Units |
|---|---|---|
| 1. Mid-side sample | | |
| a. Mean FD | FD | μm |
| b. Coefficient of variation of FD | CVFD | % |
| c. Staple strength | SS | N / ktex |
| 2. Along the staple | | |
| a. Mean, Max and Min FD | | |
| Mean FD | FDMEAN | μm |
| Maximum FD | FDMAX | μm |
| Minimum FD | FDMIN | μm |
| b. Variation of FD | | |
| Coefficient of variation of Fibre Diameter | ACVFD | % |
| Adjacent Differences | ADJDIFF | $(\mu m)^2$ |
| Difference between FDMIN and FDMAX | MAX-MIN | μm |
| Rate of Fibre Diameter Change | RATE | μm/snippet |
| c. Coefficient of Variation of Fibre Diameter within each snippet | CV1[A],...,CV10 | % |

[A] refers to snippet number, with 1 = snippet 1,......,and 10 = snippet 10.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*Statistical Analysis*

Heritabilities and phenotypic correlations were estimated using ASREML (Gilmour et al., 1998). An animal model including the fixed effects of stud (4), age of dam (2-4 years), and type of ewe birth and rearing class (single raised as single, twin raised as single, twin raised as twin, triplet raised as single and triplet raised as twin) and type of lamb birth and rearing (single died, single raised as single, multiple died, multiple raised as single and multiple raised as twin) was fitted to the data. Parameter values for CV1 to CV10 were very similar and therefore they were averaged to simplify presentation (Table 2).

## Results

Fibre diameter varied along the staple with the lowest mean fibre diameter occurring in snippet 7, and the greatest mean fibre diameter in snippet 4 (Figure 2). This represents wool growth during approximately April and January, respectively (Figure 1). At any given time during the year, with the range of fibre diameter between 14.2mm to 35.2mm there were sheep producing a fibre of approximately twice the diameter of other sheep (data not shown).

**Fig. 2 Fibre diameter variation along the staple (FDMEAN and STD in each snippet).**

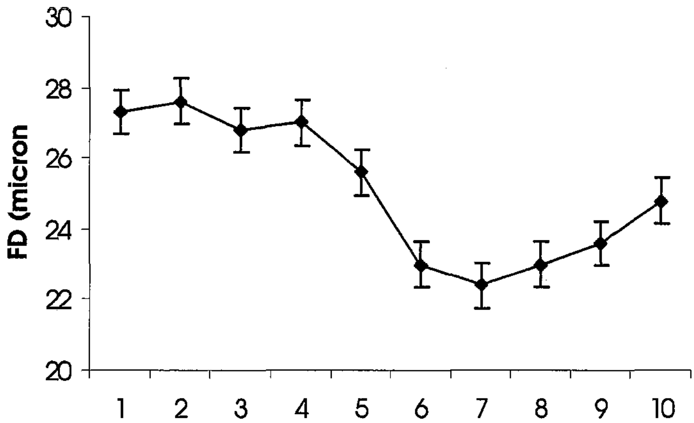


Table 2 shows the means, phenotypic standard deviations and heritabilities of each of the traits. FD, CVFD, CV1-10, FDMEAN, FDMAX and FDMIN were all highly heritable. By contrast, the remaining traits were moderately or lowly heritable, in particular RATE had a near zero heritability.


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**Table 2. Means, phenotypic standard deviations ($\sigma_p$) and heritabilities [$h^2$ (s.e)] for the traits**

| TRAIT | Mean | $\sigma_p$ | $h^2$ (s.e) |
|---|---|---|---|
| **Midside sample** | | | |
| FD | 24.91 | 2.14 | 0.60 (0.16) |
| CVFD | 22.55 | 2.5 | 0.78 (0.17) |
| SS | 28.1 | 11.09 | 0.24 (0.11) |
| **Along the staple** | | | |
| ACVFD | 9.36 | 2.73 | 0.17 (0.10) |
| ADJDIFF | 3.46 | 2.23 | 0.13 (0.09) |
| FDMIN | 21.49 | 2.53 | 0.47 (0.15) |
| FDMAX | 28.11 | 2.36 | 0.57 (0.16) |
| FDMEAN | 25.09 | 2.27 | 0.55 (0.16) |
| MAX-MIN | 6.62 | 1.81 | 0.20 (0.10) |
| RATE | -1.49 | 0.95 | 0.01 (0.07) |
| CV1-10 | 17.83 | 2.7 | 0.59 (0.16) |

Phenotypic correlations among the traits are reported in Table 3. Of the variables measured along the staple, ACVFD, FDMIN, FDMEAN and MAX-MIN had the strongest correlations with SS. However, such correlations were not very different from the corresponding value for CVFD (i.e. measures of along the staple variability were not more informative than a single measure from the mid-side sample). The remaining phenotypic correlations were either low or very low, although, they were in the expected direction. Also of interest is the high correlation between CV1-10 and CVFD but only a moderate correlation between ACVFD and CVFD.

**Table 3. Phenotypic correlations between FD, CVFD and SS of mid-side samples and the FD variability traits along the staple.**

| TRAIT | FD | CVFD | SS |
|---|---|---|---|
| **Midside sample** | | | |
| FD | 1.00 | -0.13 | 0.32 |
| CVFD | -0.24 | 1.00 | -0.44 |
| SS | 0.32 | -0.44 | 1.00 |
| **Along the staple** | | | |
| ACVFD | -0.28 | 0.48 | -0.43 |
| ADJDIFF | 0.11 | 0.25 | -0.24 |
| FDMIN | 0.83 | -0.30 | 0.47 |
| FDMAX | 0.84 | 0.00 | 0.19 |
| FDMEAN | 0.92 | -0.13 | 0.41 |
| MAX-MIN | 0.02 | 0.41 | -0.39 |
| RATE | -0.10 | -0.11 | 0.15 |
| CV1-10 | 0.69 | 0.73 | -0.3 |

Standard errors for the phenotypic correlations ranged from 0.01 to 0.04.


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## Discussion

In general, a greater mean for a biological trait is associated with greater variability. However, in this study FDMAX had a greater mean value than FDMIN, but the phenotypic standard deviation of FDMIN was greater than that of FDMAX. This indicates that variability in the response to conditions conducive to a decrease in FD was greater than to conditions conducive to an increase in FD.

ACVFD had a greater phenotypic standard deviation than CVFD and CV1-10, but it only had a low heritability. This suggests that a major component of the phenotypic variation of FD along the staple (ACVFD) is environmental rather than genetic in origin. Nutrition plays a major role (Hynd 1989; Earl et al. 1994) and variations occurring during the period of wool growth are often associated with seasonal fluctuations in pasture quality and availability (Ryder 1956; Hansford and Kennedy 1990). Phenotypic correlations among these measurements indicate that the more common measure, CVFD, was strongly associated with CV1-10 but only moderately with ACVFD. This suggests that a greater proportion of the variation in CVFD can be explained by variation within snippet (CV1-10) than along staple variation (ACVFD). ACVFD and CVFD had similar phenotypic correlations with SS, but the correlation between CV1-10 and SS was weaker than between ACVFD or CVFD and SS.

This result, combined with the estimated heritability values for these measurements, suggest that CVFD is a better indicator trait of SS than ACVFD and CV1-10. CVFD is also more practical to use as this trait is easier and less expensive to measure than ACVFD. The heritabilities for fibre diameter, coefficient of variation of fibre diameter and staple strength in this study are less accurate than those that have been estimated on larger populations. However, a large study (2170 40 month old ewes that are progeny of 155 sires) the heritabilities of FD, CVFD and SS were 0.68, 0.69 and 0.33 respectively (J.A. Hill, unpubl. data), which were similar to those found in this study (Table 2).

The stronger phenotypic correlation between SS and FDMIN than between SS and FDMAX supports previous findings reported by Bigham et al. (1983) who suggest that wool fibres are most likely to break at the point of lowest fibre diameter within the staple. The positive correlation between SS and FDMIN indicates that to improve SS it would be necessary to select for an increased FDMIN. This would however result in wool with less desirable properties and consequently FDMIN is unlikely to be appealing as an indirect indicator to improve SS. The remainder of the fibre diameter variability measures had very low to low correlations with SS, which suggests that they would also be poor indicator traits for SS.

Since the correlations calculated in this study were phenotypic only (not genetic), recommendations regarding indirect selection criterion of SS based on the traits correlated should be treated with caution. However, previous work showed that the difference between phenotypic and genetic correlations was not significant for some morphological characters (Koots and Gibson, 1994; Roff, 1996) which indicates that phenotypic correlations may be used as predictors of genetic correlations.

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## Conclusion

Concern has often been raised as to whether the measure of the coefficient of variation of fibre diameter in a mid-side wool sample is the best indicator trait for SS performance. It was thought that fibre diameter variation along the fibre could be an important contributor to lower SS, and therefore selection should concentrate on reducing ACVFD (variation along the staple), rather than CVFD (between and along fibres in mid-side). However, our results suggest that there would be no advantage in using variability of FD along the staple when trying to predict SS. Since the sheep used in this work were 4.5 year old ewes, these results are applicable to mature ewes and may not be the same in hoggets, lambs or rams.

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