SKIN FOLLICLE DEPTH AND CURVATURE HAVE LIMITED ASSOCIATION WITH FLEECE VALUE OF FINE WOOL MERINOS

J.L. Smith, I.W. Purvis and A.A. Swan

CSIRO Livestock Industries, Armidale, NSW 2350

SUMMARY
Skin follicle characteristics in vertical section were measured on fine wool Merinos. Greasy fleece weight and mean fibre diameter were not phenotypically associated with follicle depth or curvature. However, there were low to moderate correlations between these follicle characteristics and staple length (0.45 and -0.30 for follicle depth and curvature, respectively) and crimp frequency (-0.35 and 0.45 for follicle depth and curvature, respectively).

Keywords: Merino, wool, follicle depth, follicle curvature, wool production.

INTRODUCTION
‘Straight’ and ‘tangled’ wool follicle arrangements were described by Nay (1966). Subsequent studies indicated that follicle morphology was associated with crimp frequency (CF) and wool production (Nay and Johnson 1967; Nay and Hayman 1969). However, Davis and McGuirk (1987) noted these and similar studies were generally based on small unreplicated groups from single trait selection lines and the responses observed possibly affected by random genetic drift and inbreeding.

Early studies showed CF to have negative and low phenotypic correlations, and at least low to moderate genetic correlations with clean fleece weight (CFW), staple length (SL) and mean fibre diameter (MFD) (e.g. Turner 1964). Indications from the CSIRO Fine Wool Project flock (FWP) are that the correlations between CF and CFW and CF and MFD are in fact low to negligible (Smith et al. 2001). Follicle curvature has been observed to be associated with CF and CFW (Nay and Johnson 1967; Nay and Hayman 1969). Nay and Johnson (1967) were of the opinion that fibre crimp was a close reflection of follicle curvature. Hynd (1995) investigated the potential of certain early age skin and follicle traits as indirect selection criteria for adult wool production, but concluded that with the current knowledge, they should only be used as a final, independent culling measure.

This study further quantifies the relationships between follicle traits in vertical section and wool production in fine wool Merinos.

MATERIALS AND METHODS
Sheep. 300 wethers representing the 9 fine/superfine bloodlines from the 1997 drop of the CSIRO FWP (Swan et al. 2000a) were measured for a range of follicle traits in vertical section. The sheep had been selected based on low hogget (10mo) fibre diameter for another experiment, but all bloodlines were represented by at least 20 animals. The wool and skin samples for this study were collected prior to (at 21mo) the second shearing. Fleece traits measured included: MFD, SL, CF, greasy fleece weight (GFW), coefficient of variation of FD (CVD), staple strength (SS) and a suite of assessed style traits including handle, character and an overall style grade (Lax et al. 1995).
Follicle measurements. Midside skin biopsies were prepared for vertical sections based on the methods of Maddocks and Jackson (1988), and objectively measured using computer-assisted image analysis. Sections were scanned at low magnification for follicles intact and visible for their entire length. A maximum of 40 follicles per animal were measured. Follicle depth (O_DEP), follicle chord (O_CHO) and curve height (O_CURV) were measured according to the method of Nay and Johnson (1967) and follicle curvature index (O_CIND) was calculated as (follicle chord/curve height) * 100. Bulb diameter (O_BULB) was measured as the maximum diameter of the bulb in a direction perpendicular to the axis of the papilla.

Fleece value. Fleece value of individual animals was estimated using the method described by Swan et al. (2000b). Briefly, three consecutive seasons (1997-98 to 1999-2000) of wool auction sale data from the New England Wool Statistical Area (N03) were analysed by using multiple regression methods fitting MFD, SL, SS, vegetable matter and style grade. Estimated regression coefficients from this analysis were used to predict a price per kg clean for each animal based on individual measurements of MFD, SL, SS and style grade. Since yield was not measured, fleece values for each animal were then estimated as price per kg clean * GFW * 0.75.

Data analyses. The data were analysed using ASREML (Gilmour et al. 1999). A multivariate model including the traits GFW, MFD, SL, CF, O_DEP, O_BULB, O_CIND, handle, character and style was fitted to estimate a residual covariance matrix, from which phenotypic correlations were estimated. The fixed effects fitted in the model included: bloodline, birth-rearing type, age of dam, management flock and shearing interval. Predicted bloodline means were also calculated from this multivariate model. Phenotypic correlations between fleece value, O_DEP and O_CIND were estimated in the manner described above. The follicle depth and curvature residuals from this analysis were then plotted against the fleece value residuals.

RESULTS
Bloodline effects were significant for all traits. The predicted bloodline means in Table 1 indicate that bloodlines 2 and 3 tended to have higher GFW and longer SL, lower CF, and also greater follicle depth, lower follicle curvature and smaller follicle bulbs, but these associations were less discernible across all bloodlines.

Table 1. Predicted bloodline means and standard errors for fleece and follicle traits

<table>
<thead>
<tr>
<th>Trait</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>Overall Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>GFW (kg)</td>
<td>2.5</td>
<td>3.2</td>
<td>3.3</td>
<td>3.0</td>
<td>2.7</td>
<td>2.5</td>
<td>2.7</td>
<td>2.5</td>
<td>2.5</td>
<td>2.5</td>
<td>0.07 - 0.09</td>
<td>2.8</td>
</tr>
<tr>
<td>MFD (µm)</td>
<td>16.7</td>
<td>17.1</td>
<td>17.1</td>
<td>16.7</td>
<td>16.8</td>
<td>17.1</td>
<td>17.3</td>
<td>16.3</td>
<td>17.1</td>
<td>0.16 - 0.19</td>
<td>16.9</td>
<td></td>
</tr>
<tr>
<td>SL (mm)</td>
<td>62</td>
<td>63</td>
<td>65</td>
<td>59</td>
<td>61</td>
<td>57</td>
<td>60</td>
<td>58</td>
<td>62</td>
<td>1.2 - 1.5</td>
<td>61</td>
<td></td>
</tr>
<tr>
<td>CF (cr/cm)</td>
<td>7.7</td>
<td>6.0</td>
<td>5.7</td>
<td>6.5</td>
<td>7.3</td>
<td>8.3</td>
<td>6.9</td>
<td>7.3</td>
<td>7.8</td>
<td>0.23 - 0.28</td>
<td>7.1</td>
<td></td>
</tr>
<tr>
<td>O_DEP (µm)</td>
<td>1179</td>
<td>1218</td>
<td>1268</td>
<td>1198</td>
<td>1189</td>
<td>1126</td>
<td>1188</td>
<td>1181</td>
<td>1188</td>
<td>22 - 26</td>
<td>1193</td>
<td></td>
</tr>
<tr>
<td>O_BULB (µm)</td>
<td>70.4</td>
<td>67.2</td>
<td>68.1</td>
<td>67.5</td>
<td>71.2</td>
<td>72.7</td>
<td>72.1</td>
<td>69.9</td>
<td>72.4</td>
<td>0.9 - 1.1</td>
<td>70.2</td>
<td></td>
</tr>
<tr>
<td>O_CIND (units)</td>
<td>12.8</td>
<td>8.8</td>
<td>7.7</td>
<td>8.1</td>
<td>9.4</td>
<td>12.0</td>
<td>10.4</td>
<td>10.8</td>
<td>11.5</td>
<td>0.6 - 0.7</td>
<td>10.2</td>
<td></td>
</tr>
</tbody>
</table>
GFW was not correlated with any of the follicle traits and MFD was only correlated with bulb diameter (Table 2). There were moderate correlations between follicle depth and SL and between follicle curvature and CF. Style grade, character and handle were poorly correlated with follicle characteristics (ranging from -0.23 to 0.15), with the exception of follicle curvature with handle (0.29). Among the follicle characteristics, follicle depth and curvature were correlated (-0.44), as were follicle curvature and bulb diameter (0.31), but follicle depth and bulb diameter were not (0.16).

Table 2. Phenotypic variance ($V_p$) of follicle traits and correlations (standard errors in brackets) between wool production and vertical skin follicle traits

<table>
<thead>
<tr>
<th>Trait</th>
<th>$V_p$</th>
<th>GFW</th>
<th>MFD</th>
<th>SL</th>
<th>CF</th>
</tr>
</thead>
<tbody>
<tr>
<td>O_DEP</td>
<td>11162</td>
<td>0.15 (0.06)</td>
<td>-0.05 (0.06)</td>
<td>0.45 (0.05)</td>
<td>-0.35 (0.05)</td>
</tr>
<tr>
<td>O_BULB</td>
<td>18.6</td>
<td>0.01 (0.06)</td>
<td>0.32 (0.05)</td>
<td>0.06 (0.06)</td>
<td>0.19 (0.06)</td>
</tr>
<tr>
<td>O_CIND</td>
<td>8.7</td>
<td>-0.12 (0.06)</td>
<td>0.17 (0.06)</td>
<td>-0.30 (0.05)</td>
<td>0.45 (0.05)</td>
</tr>
</tbody>
</table>

The phenotypic correlation between follicle depth and fleece value was 0.19 (±0.06) and between follicle curvature and fleece value was -0.22 (±0.06). Figures 1 and 2 demonstrate slight trends indicating that productivity, expressed as fleece value, increases to a limited extent with increasing follicle depth and declining follicle curvature.

DISCUSSION

Some vertical follicle traits are associated phenotypically with fleece traits and fleece value, but these relationships appear to be weaker than initially indicated by Nay and his colleagues. For example, the correlation between CF and follicle depth in this study is almost half that previously estimated for fine wool sheep by Nay and Hayman (1969) (-0.63). The correlation between follicle depth and SL was moderate, and similar to that of Nay and Hayman (1969) (0.41), but that correlation does not seem to influence fleece value calculated using CFW, MFD, SL, SS and style grade. The correlations among SL and CF with follicle depth and curvature in this study were considerably higher than those previously estimated by Jackson et al. (1975). This may suggest strain differences in the relationships between vertical follicle traits and fleece traits. The results of the present study may
have been influenced by the nature of the selected group. In particular, the variance of MFD and O_BULB may have been lower than an unselected group, which could result in the over-estimation of correlations involving those traits.

This study indicates that vertical follicle characteristics are not associated with wool character or style. Nay and Johnson (1967) suggested that fibre crimp is a reflection of follicle shape and therefore wools of good character (good crimp definition and fibre alignment) might also exhibit well aligned, straight follicles. This study shows no evidence of such a relationship.

The critical characteristic of any breeding objective is selection, either directly or indirectly on traits that maximise economic gain. These follicle characteristics were objectively measured and the relationships with wool traits generally weak. The relationships with (indirect) assessed follicle traits, as described by Nay and Jackson (1973) are likely to be even weaker. Accurate genetic parameters could not be estimated from this data set, but if phenotypic parameters were used as a guide, vertical follicle traits would be of little use as indirect selection criteria. However, regardless of the relationship (or lack thereof), with fleece traits, the cost of measurement of vertical follicle characteristics, makes them of no real benefit to Merino breeding programs.

ACKNOWLEDGEMENTS
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