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CAN SELECTION FOR SKIN TRAITS INCREASE THE RATE OF GENETIC PROGRESS IN MERINO BREEDING PROGRAMS?

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SUMMARY

There is widespread interest in the use of skin properties for the selection of superior Merino genotypes. This is despite the fact that no selection experiments to date have demonstrated beneficial effects on production traits from selection based solely on skin traits. Two studies have examined whether the inclusion of skin traits in a realistic selection program improves the rate of genetic progress towards a breeding objective emphasising fleece weight and fibre diameter. Both indicated little benefit from including the skin traits. However the impact of the skin traits will depend on their heritabilities and their genetic associations with one another and with the traits in the breeding objective. There is increasing evidence that the genetic parameters differ between the Merino strains so results from one strain cannot be extrapolated to another. In this paper we examine the effects of including classer assessed skin quality and two objectively measured skin characters, skin biopsy weight and follicle density, on the genetic and economic gain made over and above that made using a standard selection index in South Australian Strongwool Merinos. The results indicate that substantial additional genetic gain can be made by including the skin traits. This was particularly true at low micron premiums where addition of all three skin traits increased the economic gain by 25%. The genetic improvement in adult clean fleece weight by including all three skin traits at this premium, was increased from 0.9% per annum to 1.4% per annum with a corresponding slight reduction in the decrease in mean fibre diameter. At higher micron premiums the benefit of including the skin traits was substantially less, again reflecting the tendency for skin trait inclusion to influence fleece weight to a larger extent than fibre diameter. Inclusion of the skin traits had little impact on coefficient of variation of fibre diameter, staple strength and staple length. Our results suggest that consideration of some skin traits may lead to moderate genetic gains and be worthwhile including in breeding programs for Strongwool Merinos, but they do not lend support to notions that consideration of skin traits will produce dramatic increases in fleece weights with concomitant large decreases in fibre diameter.

Keywords: skin traits, Merino, selection

INTRODUCTION

The relationship between skin traits and economically important wool characters has been the subject of considerable interest for almost 50 years in the Australian Merino breeding industry and this interest shows no signs of abating. Indeed there is currently vigorous debate within the industry regarding the relative efficiencies of selection based largely on objective fleece measurement, and selection based largely on visual and tactile assessment of the skin and fleece. However, selection on indirect traits such as skin characters will only be effective if they are more accurate indicators of lifetime wool production when measured on young animals; if they increase the accuracy of identification of superior individuals already objectively measured for fleece characters; or if they are cost-effective alternatives to objective measurement (Hynd 1995). Considerable research has been conducted into skin traits and their relationships to economically important characters, but to date none have been shown to satisfy the above criteria, despite the fact that the heritabilities, genetic correlations with fleece characters and realised responses of the skin traits to selection are in some instances moderate to high (Tables 1 and 2). There have only been two studies of the additional value of including skin traits as selection criteria for Merino sheep. Skerritt (1995) found that inclusion of follicle density, primary follicle density and S/P ratio resulted in little additional genetic gain over an index selection system for Mediumwool Merinos. Similarly Purvis and Swan (1997) concluded that for Finewool Merinos inclusion of follicle density after index selection contributed little extra economic value. These findings appear to be in conflict with some sectors who maintain that consideration of skin traits greatly increases the rate of genetic progress towards increased fleece weights and decreased fibre diameter. In this paper we briefly review the current state of knowledge of the genetic relationships between skin and fleece traits and we speculate on possible reasons for observed outcomes of skin-based selection. We then evaluate the consequences of including subjectively classer-assessed skin quality, and objectively measured skin biopsy weight, and follicle density as additional selection criteria, on the genetic improvement of wool traits in South Australian Strongwool Merinos.

Heritabilities and genetic correlations of skin traits In general skin traits are moderately heritable (Table 1). Their genetic correlation with clean fleece weight is generally low to moderate, and with fibre diameter moderate to high (Table 2).

Table 1. Heritability of some skin traits for Strongwool, Mediumwool and Finewool Merinos

Trait	Strongwool	Mediumwool	Finewool
S/P	.30[a]	.21[b], .45[c]	.52[d]
DE	.18[e], .62[h], 33[a]	.20[b], .42[f], .31[g], .40c	.46[d]
DEP	-	.37[c]	-
CRV	-	.40[c]	-
ST	.60[a]	-	-
SW	.17[e]	-	-
SQ	.36[e]	-	-

[a] Gregory (1982a); [b] Mortimer (1987); [c] Jackson et al. (1975); [d] Purvis and Swan (1997); [e] Hill et al. (1997a); [f] Brown and Turner (1968); [g] Young et al. (1960); [h] Schinckel (1958)

S/P = ratio of secondary to primary follicles; DE = follicle density; DEP = follicle depth; CRV = follicle curvature; ST = skin thickness; SW = the weight of a 1cm diameter skin biopsy; SQ = classer assessed skin quality

The skin traits examined in the selection exercise in the latter part of this paper (skin biopsy weight (SW), skin quality (SQ) and follicle density (DE)) had moderate to high heritabilities. Skin quality had a high genetic correlation with clean fleece weight but was poorly associated with diameter, implying that it might be a useful trait in a breeding program. Skin biopsy weight was negatively associated with clean fleece weight and positively with mean fibre diameter, suggesting that it might be a useful trait for selection programs with a breeding objective containing these wool traits. It was anticipated that skin biopsy weight would be an indirect measure of skin thickness as the two are highly correlated (A. J. Williams, unpubl. data), but their genetic correlations with clean fleece weight were opposite in sign. We have no explanation for this apparent paradox at present.

Table 2. Genetic correlations between skin and follicle traits for Strongwool (S), Mediumwool (M) and Finewool (F) Merinos

	Clean	fleece	weight	Mean	fibre	diameter
Trait	S	M	F	S	M	F
S/P	.37[a]	.06[b], .32[c]	.12[d]	-.20[a]	-.40[b], -.45[c]	-.45[d]
DE	.28[a], .54[e]	-.01[b], .30[f], -.02[c]	.13[d]	-.56[a], -.70[h], -.37[e]	-.67[b], -.63[f], -.66[c]	-.68[d]
DEP	-	.36[c]	-	-	.16[c]	-
CRV	-	-.45[c]	-	-	.32[c]	-
ST	.39[a]	-	-	.20[a]	-	-
SW	-.37[e]	-	-	.38[e]	-	-
SQ	.65[e]	-	-	.07[e]	-	-

[a] Gregory (1982b); [b] Mortimer (1987); [c] Jackson et al. (1975); [d] Purvis and Swan (1997); [e] Hill et al. (1997b); [f] Brown and Turner (1968); [g] Young et al. (1960); [h] Schinckel (1958). Abbreviations as for Table 1.

Consequences of selection on skin traits From the data in Tables 1 and 2 one might expect that single trait selection for high S/P ratio, deep follicles, straight follicles and possibly high follicle density would result in increased clean fleece weights. This does not appear to be the case. As indicated by Davis and McGuirk (1987), the few skin trait selection lines which have been developed indicate that selection for S/P ratio decreased clean fleece weight slightly (Rendel and Nay 1978) as did selection for increased follicle depth and increased follicle density (Jackson and Nay unpubl. data). Hynd (1995) has proposed that the main determinant of wool output per unit area of skin is the total quantity of mitotically active bulb tissue within that area, and that the failure of single trait selection reflects the fact that changes in the character under selection are opposed by concomitant changes in another character. The result is no net increase in follicle bulb tissue, hence no increase in fibre output. To effect a net increase in bulb tissue would require selection on more than one trait. Indeed the two-trait selection lines for follicle depth and density, which would be expected to increase total bulb tissue, resulted in a small but positive response in clean fleece weight (Davis and McGuirk 1987). The only other means by which the efficiency of fibre output might be improved would be for the efficiency of follicle function to be increased.

For instance if the efficiency of distribution of bulb cells to fibre were increased this might be expected to greatly augment fibre output per follicle with no change in nutrient input. Hynd (1989) estimated this cell distribution in seven sheep and found that there was considerable variation between individuals but little effect of nutrition, raising the hope that the observed variation in cell distribution might have a genetic component. Butler and Wilkinson (1979) made an indirect measurement of cell distribution using follicle morphology. They found that sheep with a greater ratio of fibre to fibre-plus-inner root sheath, had greater wool growth efficiency. Further studies of the potential of follicle morphology for identifying sheep with more efficient follicles could be warranted. Alternatively, another means of selecting for more efficient follicles might be to select sheep with fibres containing lower levels of cysteine (Williams 1987). We have measured the proportion of the fibre occupied by the high-cysteine containing paracortical cells in Strongwool Merinos. Paracortex percentage was highly heritable (0.33 ± 0.072) and was genetically associated with clean scoured yield (-0.47), clean fleece weight (-0.31), fibre diameter (+0.15), staple length (-0.17), staple strength (-0.12) and crimp frequency (+0.29) in the study reported by Hill et al. (1997a, b). Again further studies of the potential for paracortex percentage or traits correlated with it (e.g. crimp frequency) to increase the accuracy of selection, might be beneficial.

Genetic change in economic terms and in wool traits as a consequence of adding skin character information to an index The phenotypic and genetic parameters assumed in this study are shown in the Appendix table. They consist of a combination of estimates obtained in the South Australian Merino Turretfield Resource Flock (Gifford et al. 1993) with 'accepted' values currently used in Central Test Sire Evaluation for Medium and Strongwool Merinos. A simple breeding objective was defined, which included the hogget and adult expressions of clean fleece weight, average fibre diameter and coefficient of variation of fibre diameter. The economic values were calculated for three different micron premiums (5, 10 and 15%). The effect of a unit change in the coefficient of variation of fibre diameter was assumed to be equal to one fifth of the effect of a unit change in average fibre diameter. It was assumed that all selection criteria were recorded in the sheep as yearlings (10 months). Genetic change was calculated for a standard index (BASE) which included clean fleece weight, average fibre diameter and coefficient of variation of fibre diameter as selection criteria, and then for indices that included the skin traits in all possible combinations. The genetic change was calculated for a period of 10 years, assuming that the ratio of average selection intensity in males and females to generation interval in males and females was 0.4. Within each micron premium the genetic gain in economic units for the standard index was set at 100, and gain from the other indices were expressed relative to this value.

Results are presented in Table 3. The largest gains in economic value by adding the skin traits occurred at the lowest micron premiums. At the 5% premium a 6 to 9% increase in economic value occurred with the addition of single skin traits. Two skin trait addition improved gains by 16 to 19%, and addition of all three skin traits resulted in a substantial gain of 25%. A similar trend, but at reduced levels, occurred at the 10% premium. At the highest micron premium there was little improvement (2 to 6%) in progress towards the economic objective by addition of any combination of the skin traits. In terms of response in the fleece characters the different selection strategies resulted in similar changes in fibre diameter and coefficient of variation of fibre diameter. In contrast, gain in clean fleece weight at both hogget and adult ages was substantially increased by addition of the skin traits. In absolute terms genetic gain in clean fleece weight was greater the lower the micron premium, but the increase in genetic gain when skin traits were used in the index was proportionally greater the higher the micron premium. Of the skin traits examined, the estimation of skin quality and measurement of skin weight are inexpensive relative to the measurement of follicle density. The increases in economic gain by including both skin quality and skin weight are therefore of some interest. At the 5%, 10% and 15% micron premiums the extra benefit of including these two traits was 19%, 11% and 6% respectively. The benefit/cost of including these two traits is likely to be favourable and worthy of consideration. The consequences for staple strength and staple length of including skin traits in the index were negligible (range -0.24 to 0.15 N/kTex per 10 years, and 0.91 to 2.10mm per 10 years respectively).

Conclusions The increases in genetic progress towards the breeding objective which were conveyed by addition of some skin traits, while not spectacular, were of sufficient magnitude to suggest they may be usefully incorporated into some Merino selection programs, particularly those in which selected sires are likely to be used over a large number of ewes. The extra benefit obtained by including the skin traits was greater than that reported by other workers (Skerritt 1995; Purvis and Swan 1997). This may reflect differences in the genetic parameters established for the different strains and flocks (Tables 1 and 2), differences in the skin traits used, or both. For instance in the Finewool sheep the genetic correlation between follicle density and clean fleece weight was only 0.13 (Purvis and Swan 1997) whereas in the Strongwool sheep in our study the genetic correlation between density and fleece weight was 0.54. This may reflect real differences in the association between these characters in the two strains but may also reflect the fact that density was measured by two different methods in the two trials. However, in none of the selection exercises conducted to date using skin traits as selection criteria has there been evidence of spectacular increases in the rate of progress towards the breeding objective of increased fleece weight and decreased fibre diameter. Our results point to moderate additional gains but do not support suggestions that selection for skin traits will result in large changes in fleece quantity and quality. Note that this could be due to the specific sub-set of skin traits measured to date. It remains to be seen whether consideration of criteria based on the efficiency of fibre production at the follicle level, or on fibre composition, will result in more substantial increases in the efficiency of identification of superior wool producing genotypes.

Table 3. Predicted genetic change over 10 years in economic value ($obj relative to BASE = 100) and hogget (h) and adult (a) clean fleece weight (CFW %), average fibre diameter (FD µm), and coefficient of variation of fibre diameter (CVFD %) from selection strategies using a standard index (BASE) or the index plus skin quality (SQ), skin biopsy weight (SW), or follicle density (DE) alone or in combination.

Selection criteria	Micron prem. %	rel. $obj.	hCFW	aCFW	hFD	aFD	hFDCV	aFDCV
BASE	5	100	12.9	9.6	-0.9	-0.9	1.0	1.0
+ SQ	5	106	14.2	11.2	-0.7	-0.7	0.8	0.8
+ SW	5	109	14.1	11.1	-0.9	-0.9	0.8	0.8
+ DE	5	109	14.2	11.5	-0.8	-0.7	0.8	0.8
+SQ +SW	5	119	15.5	12.7	-0.7	-0.7	0.6	0.7
+SQ +DE	5	116	15.4	12.9	-0.6	-0.6	0.6	0.6
+SW +DE	5	119	15.3	12.8	-0.8	-0.8	0.7	0.7
+ALL	5	125	16.5	14.2	-0.7	-0.6	0.5	0.5
BASE	10	100	6.5	2.2	-1.9	-2.0	0.4	0.4
+ SQ	10	105	7.8	3.6	-1.9	-1.9	0.3	0.3
+ SW	10	109	8.2	4.2	-1.9	-1.9	0.3	0.3
+ DE	10	107	8.0	4.1	-1.9	-1.9	0.2	0.3
+SQ +SW	10	111	9.5	5.6	-1.9	-1.8	0.2	0.2
+SQ +DE	10	109	9.2	5.4	-1.8	-1.8	0.2	0.2
+SW +DE	10	114	9.5	5.8	-1.8	-1.8	0.2	0.2
+ALL	10	116	10.7	7.1	-1.7	-1.7	0.1	0.2
BASE	15	100	2.7	-1.7	-2.3	-2.4	0.0	0.1
+ SQ	15	102	3.5	-0.8	-2.3	-2.3	0.0	0.0
+ SW	15	105	4.3	0.1	-2.3	-2.3	0.0	0.0
+ DE	15	103	3.9	-0.3	-2.3	-2.3	0.0	0.0
+SQ +SW	15	106	5.1	1.0	-2.2	-2.3	0.0	0.0
+SQ +DE	15	103	4.6	0.5	-2.2	-2.2	0.1	0.0
+SW +DE	15	106	5.3	1.4	-2.2	-2.2	0.0	0.0
+ALL	15	104	6.2	2.2	-2.2	-2.2	-0.1	0.0

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Appendix. **Estimates of the phenotypic and genetic parameters for the wool and skin traits used in the selection exercise. Phenotypic standard deviations (σ_p), heritabilities (bold), phenotypic correlations (above diagonal) and genetic correlations (below diagonal) are presented for the traits measured in yearling (y), hogget (h) and adult (a) sheep. Skin traits are only for yearling measurements.**

	yCFW	yFD	yCVFD	hCFW	hFD	hCVFD	aCFW	aFD	aCVFD	SQ	SW	DE
σ_p	15.0	1.3	2.4	15.0	1.5	2.4	16.0	1.8	2.4	0.8	0.1	17.0
yCFW	**0.34**	0.25	0.00	0.55	0.15	0.00	0.40	0.20	0.00	0.40	0.06	0.09
yFD	0.15	**0.45**	-0.10	0.15	0.70	-0.10	0.20	0.60	-0.10	0.00	0.12	-0.22
yCVFD	0.20	-0.05	**0.40**	0.00	-0.10	0.70	0.00	-0.10	0.60	0.00	0.05	0.00
hCFW	0.70	0.20	0.10	**0.38**	0.25	0.00	0.60	0.20	0.00	0.32	0.00	0.07
hFD	0.15	0.90	-0.10	0.20	**0.50**	-0.10	0.20	0.80	-0.10	0.00	0.10	-0.18
hCVFD	0.20	-0.05	0.95	0.10	-0.10	**0.40**	0.00	-0.10	0.00	0.00	0.00	0.00
aCFW	0.55	0.30	0.10	0.75	0.30	0.10	**0.43**	0.30	0.00	0.26	0.00	0.06
aFD	0.15	0.80	-0.15	0.20	0.90	-0.15	0.30	**0.50**	-0.10	0.00	0.08	-0.14
aCVFD	0.20	-0.05	0.90	0.10	-0.10	0.95	0.10	-0.15	**0.40**	0.00	0.00	0.00
SQ	0.65	0.07	0.00	0.52	0.06	0.00	0.42	0.05	0.00	**0.36**	0.05	0.07
SW	-0.37	0.38	0.18	-0.30	0.30	0.14	-0.24	0.24	0.12	-0.07	**0.17**	-0.04
DE	0.54	-0.37	-0.09	0.43	-0.30	-0.07	0.35	-0.24	-0.06	0.34	-0.74	**0.18**