GENETIC PARAMETERS FOR FOLLICLE DENSITY TRAITS IN FINE-WOOL MERINOS AND BREEDING PROGRAM IMPLICATIONS

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SUMMARY

Genetic parameters for wool follicle density traits and a range of economically important traits were estimated by REML procedures using data collected from the CSIRO Fine Wool Project flock at Armidale, NSW. By using a new technology for measuring follicle density, parameter estimates were obtained for total follicles, follicles of epidermal origin (primaries plus secondary originals), secondary derived follicles and for the average distance between epidermal follicles within follicle groups. Breeding program implications of including various follicle density measurements in the selection index were examined for breeding objectives varying in the emphasis given to reducing fibre diameter while increasing fleece weight. By comparison with direct selection for clean fleece weight and fibre diameter, the density traits evaluated appear to have little potential as indirect selection criteria in Merino breeding.
Keywords: Genetic parameters, follicle density, genetic progress

INTRODUCTION

Wool follicle density is a component of fleece weight and is negatively correlated with fibre diameter. Density is usually measured in horizontal skin sections at the level of the sebaceous gland. By this method it is possible to distinguish primary and secondary follicles and to estimate the ratio of the two (S/P ratio). A new method of measuring wool follicle density has been developed which is based on shaved skin impressions and is called the SKIM method (Nagorcka *et al.* 1995; Nagorcka *et al.* 1998). Using this method, it is possible to distinguish between follicles of epidermal origin (primaries plus secondary originals) and those follicles which branch from epidermal follicles, ie., secondary derived follicles.

For the past two to three years, there has been considerable debate in the rural printed media concerning the merit of including various direct and indirect measures of density as selection criteria for Merino sheep and of the contribution that changes in density make to genetic progress in Merino breeding programs. The purpose of this paper is twofold. First, we present genetic and phenotypic parameters for density traits estimated from data produced by the SKIM technique and for other economically important and indicator traits in fine-wool Merino sheep. Second, the consequences of including various density measurements as selection criteria are analysed for breeding objectives varying in the emphasis given to reducing fibre diameter while increasing fleece weight.

MATERIALS AND METHODS

Animals. Data were collected from hogget (10 mo) ewes and wethers born in the CSIRO Fine Wool Flock at Armidale over the years 1990 to 1996. The design, management environment, measurement schedule and measurement methods for each trait for this flock have been described in detail by Swan *et al.* (1993). Measurement methods for the SKIM traits have been described in detail by Nagorcka *et al.* (1998). Data for this study were available on wool production and quality traits for all year of birth groups but skin measurements were available only for a sub-set of these groups. The complete data set comprised records on 7813 hoggets sired by 385 rams from 3571 dams. For traditional skin traits, there were records from 3788 hoggets (1990-1994 drops) sired by 257 rams from 2307 dams, while for the SKIM traits, records were available from 1350 hoggets (1995-1996 drops) sired by 123 rams from 1139 dams.

Traits and Statistical Methods. The traits considered in this analysis were clean fleece weight (cfw), mean fibre diameter (mfd, Laserscan), coefficient of variation of fibre diameter (cvfd, Laserscan), staple length (sl), total follicle density (tdss, horizontal skin section), secondary follicle/primary follicle ratio (s/p, horizontal skin section), crimp frequency (cr/cm, automated image analysis instrument, Humphries (1994)) and the traits measured using the SKIM technique – total follicle density (tdsk), density of epidermal follicles (depi), density of secondary derived follicles (dsd) and the estimated wave length of the reaction-diffusion (RD) system (wavel). The data were analysed by REML procedures using the statistical package ASREML (Gilmour *et al.* 1998). Based on significant effects identified in previous analyses of these data, the model for all traits other than cfw was a full animal model including, when significant, the fixed effects of management flock, line, age of dam, sex and age. For cfw, the model included direct and maternal genetic effects. However, in bivariate analyses involving cfw and the SKIM traits, the covariances between the cfw maternal genetic effect and the direct genetic effects for the SKIM traits were not fitted. With only two year of birth groups for the SKIM traits, there was insufficient depth of pedigree and data to estimate these covariances.

Comparison of Breeding Strategies. The value of SKIM traits as selection criteria in typical Merino breeding objectives has been evaluated using the SELIND computer program (Cunningham and Mahon 1977) by calculating expected genetic gains in the overall objective, its component traits and a number of other traits of interest for various combinations of cfw, mfd, wavel and dsd as selection criteria. For simplicity, the traits in the breeding objective were hogget cfw and mfd and gains were evaluated for two objectives with differing emphasis on reducing mfd. For males and females respectively, the breeding program design assumed the same selection criteria, proportions selected of 6 % and 50 % and generation intervals of 2.5 and 4 years.

RESULTS

The heritabilities for SKIM density traits (Table 1) are at the low end of published estimates for Merino density traits determined from traditional transverse section skin data. As expected, the correlations between total density and its component density traits are high but the correlations between the components are lower. The genetic correlations with wavel are all negative indicating that selection for reduced wavel would increase density and therefore decrease diameter. This is confirmed from the genetic correlations between the SKIM traits and other traits of interest in this study as shown in Table 2. There is a strong positive correlation between wavel and mean fibre diameter and the correlation with cfw is lower and negative. As expected, there is a very high correlation between total follicle density measured by the SKIM technique (tdsk) and by horizontal skin section (tdss). The correlations between density of secondary derived follicles (dsd) and other traits are in the expected direction.

Table 1. SKIM trait parameters. Heritabilities on, genetic correlations below and phenotypic correlations above the diagonal

Trait	Total follicle density (tdsk)	Epidermal foll. density (depi)	Sec. derived foll. density (dsd)	Wave length (wavel)
tdsk (foll./mm^2)	**0.36±0.08**	0.61±.02	0.88±0.01	-0.37±0.02
depi (foll./mm^2)	0.61±0.12	**0.26±0.07**	0.16±0.03	-0.78±0.01
dsd (foll./mm^2)	0.92±0.03	0.25±0.18	**0.39±0.08**	0.02±0.03
wavel (μm)	-0.58±0.20	-0.75±0.11	-0.36±0.26	**0.12±0.06**
Mean	84.5	38.1	46.4	113.7
Std deviation	12.45	6.10	9.97	10.35

Table 2. Genetic correlations between SKIM and other production traits in fine-wool Merinos

Trait	**cfw (kg)**	**mfd (μm)**	**cvfd (%)**	**sl (mm)**	**tdss (f/mm^2)**	**s/p**	**cr/cm**
tdsk	.37±.13	-.52±.08	-.02±.10	-.33±.11	.94±.07	.75±.09	**-.06±.13**
depi	.26±.15	-.49±.10	.07±.12	-.02±.13	.75±.12	.71±.11	**-.18±.14**
wavel	-.29±.23	.66±.16	-.13±.16	.08±.19	-.89±.19	-.91±.18	**.20±.20**
dsd	.31±.12	-.37±.08	.00±.10	-.41±.11	.78±.09	.57±.10	**.01±.13**
Mean	**1.6**	**16.6**	**17.6**	**70.9**	**83.4**	**22.1**	**6.2**
Std dev	**0.254**	**1.06**	**2.22**	**8.50**	**16.12**	**5.00**	**1.10**
h^2	**.47±.07**	**.65±.02**	**.47±.03**	**.52±.03**	**.48±.04**	**.52±.04**	**.38±.03**

Expected genetic gains after 10 years of selection for breeding objectives with 5 % and 10 % micron premiums are presented in Table 3.

Table 3. Genetic gain after 10 years of selection using a range of selection criteria for breeding objectives with a 5% or 10% micron premium

Selection Criteria traits	**Objective $/ewe life**		**cfw (kg)**		**mfd (μm)**		**sl mm**		**cr/cm**	
micron premium (%)	**5**	**10**	**5**	**10**	**5**	**10**	**5**	**10**	**5**	**10**
cfw,mfd	**37.3**	**60.0**	**.35**	**.22**	**-2.2**	**-2.7**	**3.5**	**1.4**	**-.28**	**-.12**
wavel	**11.3**	**19.0**	**.08**	**.08**	**-0.8**	**-0.8**	**-0.7**	**-0.7**	**-.20**	**-.20**
dsd	**14.9**	**22.6**	**.14**	**.14**	**-0.8**	**-0.8**	**-6.7**	**-6.7**	**.02**	**.02**
wavel,dsd	**18.9**	**29.8**	**.16**	**.16**	**-1.2**	**-1.2**	**-5.8**	**-5.7**	**-.11**	**-.12**
cfw,mfd,wavel	**37.4**	**60.2**	**.35**	**.22**	**-2.2**	**-2.7**	**3.4**	**1.3**	**-.29**	**-.14**
cfw,mfd,dsd	**37.5**	**60.1**	**.36**	**.22**	**-2.1**	**-2.7**	**2.7**	**1.1**	**-.28**	**-.12**
cfw,mfd,wavel,dsd	**37.7**	**60.3**	**.37**	**.23**	**-2.1**	**-2.7**	**2.5**	**0.9**	**-.29**	**-.14**

When the selection index includes cfw and mfd the results are as expected from previous studies. As the emphasis in the breeding objective on reducing mfd increases, the contributions of change in cfw and mfd to the overall gain are reduced and increased respectively. For both objectives there is a correlated increase in staple length and a very small reduction in crimps/cm.

By comparison with the selection index including only cfw and mfd, selection for wavel or nsd alone or for wavel plus nsd, results in one third to one half of the overall economic gain for either objective. Furthermore, the addition of wavel or nsd or both to the selection index including cfw and mfd results in very little extra gain in either objective.

DISCUSSION

The RD theory of follicle initiation and fibre growth (Nagorcka 1995 a,b) predicts that the wave length of the RD system (wavel), which is estimated in this study from the average inter-follicle distance within follicle groups, is negatively related to fleece weight and positively related to fibre diameter. The genetic correlation estimates presented in Table 2 confirm these predictions. Selection for reduced wavel should therefore lead to increased fleece weight and reduced fibre diameter. This is confirmed from the selection response data presented in Table 3. However, the level of response is only around one third of that from using cfw and mfd as the selection criteria. The heritability of wavel is too low (0.12) and the correlation with cfw is also too low (-0.29) for wavel to be a more effective selection criterion than cfw plus mfd. wavel is correlated with cfw and mfd in the required directions, but for these objectives, cfw and mfd are efficient predictors of aggregate genotype. The additional contribution to genetic progress from data on wavel is therefore minimal.

The SKIM technique also makes possible measurement of the density of secondary derived follicles (dsd). As was the case for wavel, the contribution to genetic progress for these objectives, of data on nsd, alone or over and above that from data on cfw and mfd, is minimal.

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