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INCLUDING RESILIENCE IN THE BREEDING OBJECTIVE OF SUSTAINABLE MERINO SHEEP

E.G. Smith[1], S.F. Walkom[2], A.A Swan[2] and S.A. Clark[1]

[1] School of Environmental and Rural Science, University of New England, Armidale, NSW, 2350 Australia
[2] Animal Genetics Breeding Unit*, University of New England, Armidale, NSW, 2351 Australia

SUMMARY

This study examined the effect of including an indicator trait of resilience (log variance of fibre diameter variation (FD_Lnvar)) into a current industry selection index designed to produce sustainable Merino sheep in Australia. A desired gains index was used to estimate the relative contribution of resilience to the index when either maintaining or improving (decreasing) FD_Lnvar by a quarter or half genetic standard deviation over ten years, compared to the standard index. The relative contribution of resilience needed, to achieve these goals, was shown to be 3.5, 12.4 and 25.3% respectively. Adjusting the index to maintain resilience had little impact on production traits, but prioritising higher FD_Lnvar responses reduced gains in key production traits including clean fleece weight and growth.

INTRODUCTION

General resilience describes an animal's ability to respond and recover from unspecified environmental disturbances (Colditz and Hine 2016). In sheep, general resilience can be assessed using the variability in fibre diameter measured along the wool staple, using a trait definition such as the log variance of deviations in fibre diameter (FD_Lnvar). Animals with larger trait estimates for FD_Lnvar are potentially more susceptible to environmental stresses and may have poorer health outcomes (Smith *et al*. submitted). The current MERINOSELECT indexes, released in 2024, include several traits related to susceptibility to disease and resilience including wrinkle, dag, worm egg count and condition score (Sheep Genetics 2024). However, as much as 80% of the genetic variation in FD_Lnvar is not currently explained by the traits included in this evaluation (Smith *et al*. submitted). There is interest in including resilience traits like FD_Lnvar in breeding objectives, but its economic value is hard to quantify due to the difficulty in quantifying its economic impact. A desired gains index is often useful for exploring the implications of including new traits in selection indexes where the economic benefits of improving a trait are unknown. This paper assesses the impact of adding FD_Lnvar to the Sustainable Merino (SM) index for Australian Merino sheep. A desired gains approach estimated the relative index contribution needed to maintain or improve resilience by 0.25 or 0.50 genetic SD over ten years. The effect of including resilience on genetic gain in other traits was also examined.

MATERIALS AND METHODS

Breeding objective. The SM index is based on a self-replacing ewe flock, producing 17-19µm wool and selling lambs post-weaning, off-shears. In this system, income from the production of wool and meat are approximately equal (46:54). The index prioritises genetic improvement of clean fleece weight, growth, lean meat yield (LMY) and reproduction (conception, litter size and rearing ability) while maintaining fibre diameter and staple strength. There is also a focus on reducing worm egg

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count, dag, wrinkle and mature weight (Sheep Genetics 2024). Together, the SM index includes 14 traits (Table 1), with fleece traits assessed at post-weaning, hogget and adult stages. To assess the impact of including resilience, three SM index variations were compared to the base index: (1) SM+R (zero change in FD_Lnvar), (2) SM+R0.25 (improving FD_Lnvar by a quarter) and (3) SM+R0.50 (improving FD_Lnvar by half a genetic SD). A desired gains approach was used to calculate the relative contribution of resilience to the index needed to guide selection towards improving FD_Lnvar to align with these three objectives.

Desired gains index. A desired gains index calculates trait values indirectly using index-weighting factors based on a predetermined desired or restricted amount of genetic gain for one or more traits. Here the method uses the equation of Pešek and Baker (1969): $\boldsymbol{b} = \boldsymbol{P}^{-1}\boldsymbol{G}(\boldsymbol{G}'\boldsymbol{P}^{-1}\boldsymbol{G})^{-1}\,\boldsymbol{d}$, where $\boldsymbol{b}$ is a vector of weighting factors for the selection index, $\boldsymbol{P}$ is the phenotypic variance-covariance matrix, $\boldsymbol{G}$ is the covariance matrix of the phenotypic and genotypic values and $\boldsymbol{d}$ is the vector of relative desired gains used to realise the breeding goals. The genetic parameters (phenotypic and genetic correlation and heritabilities) were sourced from Sheep Genetics (2024). The heritability of FD_Lnvar was assumed to be 0.11 and correlations between FD_Lnvar and traits in SM are shown in Table 1. The weighting factors for each trait in the index were transformed into standard trait values (STV) by multiplying the trait weighting factor by its genetic standard deviation. The relative contribution (%) of each trait to the index was calculated as: $\frac{|STV_j|}{\sum_{j=1}^{24}|STV_j|} \times 100$, where $|STV_j|$ was the absolute STV of trait j. The sign of the relative contribution was adjusted to indicate the direction of trait improvement.

Table 1. Genetic and phenotypic correlations between FD_Lnvar and traits included in Sustainable Merino (Smith *et al.* submitted). Correlations are averaged across age stages

Trait	Genetic correlation	Phenotypic correlation
Clean fleece weight	-0.10	-0.01
Fibre diameter	-0.05	-0.13
Fibre diameter CV	-0.07	0.08
Staple strength	-0.01	-0.05
Growth	-0.11	-0.07
Lean meat yield	0.08	-0.01
Mature weight	-0.05	-0.07
Condition score	-0.23	-0.02
Conception[1]	*-0.05*	*0.01*
Litter size[1]	*-0.05*	*0.01*
Rearing ability[1]	*-0.05*	*0.01*
Wrinkle	0.07	-0.01
Worm egg count	0.01	-0.05
Dag	0.08	0.01

[1]Assumed based on an informed estimate.

The genetic gain per generation from a single round of selection using a selection intensity of one was calculated as, $\boldsymbol{g} = \boldsymbol{b}'\boldsymbol{G}/\boldsymbol{\sigma_I}$, where $\boldsymbol{g}$ is a vector of genetic gain in each trait and $\boldsymbol{\sigma_I}$ is the standard deviation of the index. Annual genetic gain was derived by multiplying $\boldsymbol{g}$ by the ratio of selection intensity $\boldsymbol{i}$ and generation interval **L.** A generation interval of 3 years for males and 4 years for females was used, with selection intensities of 2.06 for males (5% selected) and 0.80 for females (50% selected). Selection was 65% index-based and 35% visual. A 30% reduction in response was assumed over 10 years due to a decrease in genetic variance. The number of half-sibling records available for each trait was: 30 for post-weaning fleece traits, weight, worm egg count, resilience, early post-weaning wrinkle and dag; 30 for hogget fleece and weight traits and lean meat yield; 7 for adult fleece traits and mature weight; and 5 for reproduction traits and condition score.

RESULTS AND DISCUSSION

Figure 1 shows the relative contribution of each trait to the index as a proportion of the total index value. Achieving zero change in FD_Lnvar required a relative contribution of -3.5%, similar to worm egg count or fibre diameter within the SM+R index. Achieving greater genetic gain in FD_Lnvar, equivalent to a quarter (SM+R0.25) or half (SM+R0.50) of a genetic SD required larger relative trait contributions of -12.4 and -25.3%, respectively. In the latter index, the increased emphasis on FD_Lnvar resulted in significant reductions in selection pressure on other traits including clean fleece weight, fibre diameter, conception and rearing ability compared to SM. For SM+R0.50 the relative trait values were around halved for all traits in the index compared to the SM. These higher contributions were necessary to achieve the specific reduction in FD_Lnvar due to the low heritability of FD_Lnvar and weak genetic correlations between FD_Lnvar and other traits in the breeding objective. This study relied on genetic parameters for FD_Lnvar estimated from a limited dataset (Smith *et al*. submitted), therefore, there is some uncertainty regarding the direction and strength of the genetic correlations. Future work could explore the sensitivity of the relative contribution to changes in the genetic correlations similar to Safari *et al.* (2006).

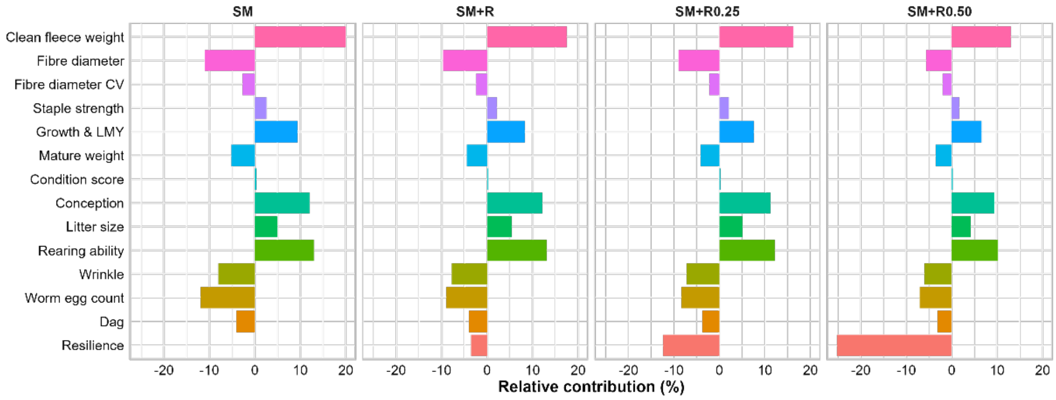

Figure 1. Relative contribution (%) of each trait to the index of Sustainable Merino (SM), including resilience (FD_Lnvar) maintained (SM+R), improving by 0.25 (SM+R0.25) or 0.5 (SM+R0.50) of a genetic SD. Traits are summed across age stages

The impacts of including selection pressure on FD_Lnvar on genetic gain in other production and health traits relative to the SM index are shown in Figure 2. The SM+R index results in an average decline in the response of 12% compared to SM. Genetic gain in wrinkle was, however, improved beyond SM in all indexes that included resilience, due to favourable correlated responses with FD_Lnvar. Despite this improvement, both SM+R0.25 and SM+R0.50 resulted in proportionally higher losses in average response of 16% and 28%, respectively, compared to SM. The response in condition score was not different between the SM and SM+R0.25 and slightly higher between SM and SM+R0.50 index, owing to its low relative contribution to the index and moderate favourable correlations with FD_Lnvar. The total index value decreased by 13, 17 and 25% in the SM+R, SM+0.25 and SM+R0.50 indexes, respectively. The decline in response in the former two indexes is possibly acceptable, although attempting to improve FD_Lnvar by half a genetic SD is unlikely to be economically viable within this breeding objective. Nonetheless, higher levels of resilience (FD_Lnvar) may be warranted in specific contexts, such as in reaction to more extreme production environments or where policy changes concerning animal welfare pose a threat to market access. Further, the current selection on the SM index results in a slight favourable decrease in FD_Lnvar, which suggests that the current SM index is unlikely to be detrimental to resilience.

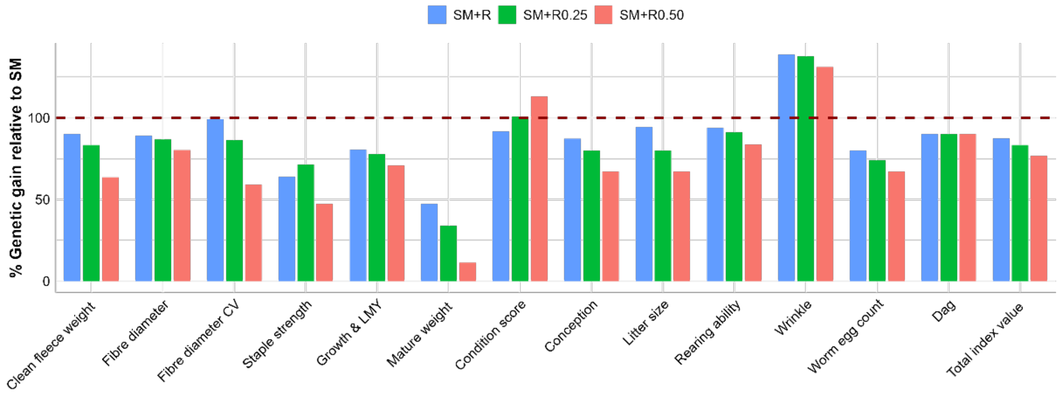

Figure 2. The proportion of genetic gain over 10 years in each trait relative to the Sustainable Merino (SM). Scenarios include maintaining resilience (SM+R) and improving by 0.25 (SM+R0.25) or 0.5 (SM+R0.50) of a genetic SD. Responses are averaged across age stages

In this study, desired gains for FD_Lnvar were chosen subjectively to illustrate the impact of selecting for resilience within the existing SM breeding objective. Future work could focus on optimising these desired gains to balance improvements in resilience with improvements in other traits. Alternatively, other methods for valuing resilience could be explored, such as a bioeconomic model. Bioeconomic models account for the complex interactions between genetics, physiology, management practices and economic parameters, and therefore may provide a more realistic assessment of how resilience traits influence profitability. These models are also better suited to evaluate uncertainty, which is important particularly for traits like resilience which affect a system's ability to adapt to disturbances.

CONCLUSION

This study demonstrated that maintaining or increasing resilience by 0.25 or 0.50 of a genetic SD in the SM index required relative contributions of -3.5, -12.4 and -25.3% respectively. Greater emphasis on resilience within these indexes led to a decline in genetic response for other important production traits, highlighting the trade-offs associated with including FD_Lnvar in the index. Further research is needed to refine the value of resilience before considering integrating FD_Lnvar into industry breeding programs.

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