Proc. Assoc. Advmt. Anim. Breed. Genet. 19:323-326

THE VALUE OF GENOMIC SELECTION FOR STUD AND COMMERCIAL MERINO RAMS

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SUMMARY

The additional value that can be gained from selecting stud and commercial rams based on genomic information was evaluated for Merino studs using two different breeding objectives. Selection index theory and gene flow methodology were used to contrast the accuracies and selection responses of indexes using phenotype information only, with those using additional genomic information of either high or low accuracy and selecting males at one year of age. With the inclusion of genomic information and earlier selection index accuracies increased and an additional 11–64% in commercial dollar value per ram could be gained from genetic improvement. The breakeven point for DNA testing was evaluated to be between $13.04 and $64.48, depending on the breeding objective and the accuracy of the genomic information.

INTRODUCTION

Genomic selection is being implemented in dairy industries internationally (Loberg and Duerr 2009). Various factors have contributed to this success, including the hierarchically integrated structures of the industry, the high accuracy that can be achieved in genomic breeding values, the sex limitation of the economically important traits, and the high value of bulls. In the beef industries, the economic benefit to a stud breeder of using genomic selection has been evaluated as ranging between 20-41%, depending on the breeding objective (Van Eenennaam 2011). The implementation of genomic selection in the Merino and terminal sire industries has been estimated to increase response to selection by up to 40%, depending on the accuracy of the trait breeding values (van der Werf 2009), and it is now trialled with industry flocks (Ball pers. comm.).

In the sheep industry genetic improvement is generated by a large number of stud breeding operations (approximately 1,000 active studs across terminal, dual-purpose and Merino sectors), each dependent on their commercial clients' operations, and thus varying in management practices and breeding objectives making potential gains from genomic selection quite variable. The aim of this study is to evaluate the economic benefits of genomic selection at the level of individual breeding operations for a range of production system of the stud's clients. The additional economic value gained through the inclusion of genomic information in selection was evaluated for rams that were either used as stud replacements or for rams sold for commercial use.

MATERIALS AND METHODS

Structures of stud and commercial operations. Two Merino stud operations were modelled using two different breeding objectives, reflecting their commercial clients' production system. One stud uses a MerinoSelect Merino 14% (M14%) index (www.sheepgenetics.org.au). This index includes reproduction and yearling and adult wool and body weight traits, but places most selection emphasis on reduction of fibre diameter while keeping clean fleece weight constant. The commercial clients of this stud run self-replacing fine wool Merino flocks, keeping a proportion of wethers for two years for wool production before selling them.

The second stud uses the MerinoSelect Dual Purpose 7% (DP7%) index (www.sheepgenetics.org.au). DP7% includes reproduction traits, yearling fat and eye muscle depth and adult and yearling wool and body weight traits. It aims at small gains in clean fleece weight, moderate reduction in fibre diameter and high gains in body weight and reproduction. The commercial clients of this stud produce dual purpose Merino sheep. Wool is of medium fibre diameter and 40% of ewes are mated to terminal sires for prime lamb production. No wethers are kept for wool production.

Economic value. The economic value of selecting a ram for stud replacement or for commercial use was evaluated by calculating index accuracies with and without genomic information using selection index theory (Lande and Thompson, 1990) and the value of selection differential of rams to commercial progeny. Accuracies and resulting trait responses for the Merino studs were evaluated using only phenotype information in the selection index (no GS) and contrasted with the responses after additionally including genomic information (GS) in the index. Rams were selected at 18 months of age. The genomic information was either of high ($r^2_{high}=h^2$) or low accuracy ($r^2_{low}=0.25*\ h^2$). The accuracy (r^2) reflects the proportion of genetic variance explained by genomic information for each individual trait and is dependent on the number of individuals with both genotypic and phenotypic records (Goddard, 2009). All rams weaned in the nucleus were genotyped. Trait heritabilities ranged from h^2 = 0.6 for fibre diameter to h^2 = 0.06 for number of lambs weaned. As yearlings, animals were measured for fibre diameter and the coefficient of variation of fibre diameter, clean fleece weight and body weight. For DP7%, yearling fat and eye muscle depth were also measured at the same time. Phenotypic and genetic parameters and economic weights for the breeding objectives, DP7% and M14%, were obtained from SheepGenetics. The value of using a genetically improved ram per unit of index superiority was calculated from the cumulative discounted expressions (CDE) using the gene flow method (Hill 1974). CDE sum the proportions of genes of a selected ram that are expressed in commercial progeny over age classes. An annual discount rate of 7% was assumed. The economic value of the genetic superiority of a stud replacement ram or a commercial ram was calculated by multiplying the index superiority ($i^*\ \sigma_{Index}$, with i = selection intensity and σ_{Index} = standard deviation of the index) of selected rams by the CDE and the number of life time progeny, as previously described by Van Eenennaam *et al.* (2011). The additional dollar value per DNA test was obtained by dividing the genetic improvement benefit (in $) per ram from GS over no GS by the number of DNA tests conducted per ram sold or used within the stud. This figure provides an estimate for the breakeven point for the application of genomic selection in a Merino operation as modelled in this study. This study did not estimate cost per ram.

Table 1. Flock structure of Merino stud operation

	Stud parameters
Weaning rate (%)	100
Ewe replacement (%)	20%
Mortality % male / female	2 / 2
No of age classes male / female	5 / 2
No of animals genotyped	All nucleus weaned males
Rams sold for breeding per year (%)	20
Rams selected for breeding within stud (%)	4
Mating ratio (Ewes : Rams)	50:1
Cumulative discounted expressions stud / commercial	1.30 / 0.45
No of lifetime progeny per commercial ram	100

RESULTS & DISCUSSION

The selection accuracy of two year old males ($r_{SelMales}$) increased with increasing accuracy of the genomic information (Table 2). It ranged from $r_{SelMales}$ = 0.37 – 0.60 for M14% and from $r_{SelMales}$ = 0.40 – 0.53 for DP7%. The inclusion of highly accurate genomic information increased selection accuracies of two year old males by 64% for M14% and by 32% for DP7%. The selection accuracies for DP7% were overall lower, because the selection index is highly dominated by the number of lambs weaned, which is a lowly heritable trait.

Table 2. Standard deviation of the breeding objective (σ_A) and the selection index (σ_{Index}), and selection accuracies of two year old males ($r_{SelMales}$) achieved for two breeding objectives (M14% and DP7%) using family information only (no GS) or adding genomic information (GS) of varying accuracies (r_{low} and r_{high})

Breeding objective (σ_A in $)*	Information for selection	$r_{SelMales}$	σ_{Index}
M14% (3.99)	no GS	0.37	1.47
	GS r_{low}	0.44	1.76
	GS r^2_{high}	0.60	2.41
DP7% (4.53)	no GS	0.40	1.82
	GS r^2_{low}	0.44	2.01
	GS r^2_{high}	0.53	2.40

The benefit of incorporating genomic information into the selection index could be observed in the additional commercial dollar value gained (Table 3). The added value ranged from 1–32% for DP7%, depending on the accuracy of the genomic information and from 11–64%, for M14% (Table 3). The resulting additional values in this study vary more widely than the predictions for a fine wool and meat sheep breeding objective calculated by van der Werf (2009), or for beef cattle, where the predicted added value from genomic selection ranged between 55-158% (van Eenennaam 2011).

Table 3. Value of genetic improvement per ram using a selection index with phenotypic information only (no GS) and with the inclusion of genomic information (GS) of varying accuracy (r_{low} and r_{high}) and the additional commercial dollar value gained per ram from including genomic information

		Value of genetic improvement (in $)			Additional $ value per ram*	
		No GS	GS r^2_{low}	GS r^2_{high}	r^2_{low}	r^2_{high}
Stud	M14%	2,058	2,464	3,374	406 (+20%)	1,316 (+64%)
	DP7%	2,548	2,814	3,360	266 (+11%)	812 (+32%)
Commercial	M14%	93	111	152	18 (+20%)	59 (+64%)
	DP7%	115	127	151	12 (+1%)	37 (+32%)

*percent of value of genetic improvement without GS in brackets

The breakeven point of the additional gain per DNA test from genomic selection ranged between $13.04 and $64.48, depending on the accuracy of the genomic information and the breeding objective of the stud (Table 4). For a beef cattle scenario, the breakeven point was higher, as can be expected, ranging between $143 - 258 (van Eenennaam 2011), mainly because the genetic variation in profit per head in beef cattle is higher than in sheep. In this study, the additional value per DNA test ranged between $4.16 and $11.84 for commercial rams and between $18.48 and $52.64 for stud rams, depending on the breeding objective and the accuracy of the genomic information. The additional value per DNA test was low with the inclusion of genomic information of low accuracy, but it was around three times as much when genomic information was of high accuracy. The values in this study provide conservative estimates, because it was assumed that all rams born were genotyped. An optimised genotyping strategy would reduce the numbers of animals tested and increase the additional value gained per DNA test. The value is also highly dependent on the proportion of stud born males sold as commercial rams and would also be influenced by the age at which animals are genotyped and subsequently selected, which was not varied in this study.

Table 4. Additional value per DNA test ($) gained from stud and commercial rams bred with M14% or DP7% breeding objective

		Additional $ per DNA test	
	Breeding objective	GS r^2_{low}	GS r^2_{high}
Stud	M14%	16.24	52.64
	DP7%	10.64	32.87
Commercial	M14%	3.65	11.84
	DP7%	2.40	7.31
Total Value	M14%	19.89	64.48
	DP7%	13.04	40.18

CONCLUSIONS

The breeding objective and the accuracy of genomic information strongly influence the additional economic benefit that can be gained from using genomic selection for stud and commercial Merino rams. The breakeven point of the additional benefit from genomic selection provides an estimate of potential maximum cost to an individual breeder for application in the Merino industry. It was low for genomic information of low accuracy. The additional benefit of using genomic technology could be increased by optimising the genotyping strategy. This study is an important step in developing cost-effective strategies for implementation of genomic testing at the stud level. Further work will be needed to account for optimisation of generation intervals, and to examine the impact of the degree to which prices paid for flock rams reflect their genetic merit.

ACKNOWLEDGEMENTS

This work was funded by Meat and Livestock Australia. The authors would like to thank Andrew Swan for his advice.

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