QPLU$

Re-visited 2018

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MerinoLink Limited fully acknowledge NSW DPI and Australian Wool Innovation for the opportunity to re-publish key papers from the 2006 and 2007 QPLU$ field day proceedings, enabling the next generation of sheep breeders and service providers access to this valuable research.

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QPLU$ Re-visited 2018

MerinoLink Limited is a not for profit organisation that aims to facilitate sheep breeders and service providers link with information, knowledge and research. The founding members of MerinoLink are from a wide range of sheep businesses with varying production systems. The members have been brought together by a common enthusiasm for profitable Merino sheep and a desire to continue to build their businesses, client businesses and the sheep industries profitability.

As a new generation of sheep breeders and service providers are coming into the industry, the MerinoLink Board felt it was timely to revisit some key industry research. QPLU$ is one of those industry research projects. MerinoLink has worked with NSW DPI to be able to re-publish key papers from the 2006 and 2007 QLPU$ field day proceedings and are presented in this publication.

MerinoLink would like to acknowledge and thank the dedication of the NSW DPI staff involved in this project from its inception to conclusion, a massive 15 years, as well as the financial support from both Australian Wool Innovation and NSW DPI.

MerinoLink is committed to assisting our members make better use of past and current research. In addition, MerinoLink aims to continue to build networks and add value to existing and future research and development. We recognise the opportunities to work together to develop research projects for the future improvement of the Australian Sheep industry.

We trust that everyone will benefit from having access to this important industry research information.

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Forward

The Trangie QPLU$ Project is a Merino breeding project that was initiated in 1992. It was designed with a number of aims:

- To demonstrate the efficiency of using a selection index to rank sheep based on measured performance.
- To provide Merino breeders with information to help them choose a balance of measured and visual selection that will achieve their breeding objective.
- To give breeders the opportunity to see the process and results of index selection first hand.

As Merino breeding technology has been developed, the use of objective measurement has become easier and more affordable. The correct use of objective measurement allows breeders to maximize their genetic progress and therefore satisfy the demands of their clients, who are in turn aiming to meet market demand.

The subject of objective measurement and the selection of sheep based on these measurements always raise questions in the wool industry:

- What sort of genetic gains are possible?
- What will happen to non-measured characteristics like wool style and conformation?
- How can we find a balance between measured and visual selection?
- What do we need to measure and what information do we need to record?

The Trangie QPLU$ Project was set up to answer these and other questions. A series of open days in the past have occurred to allow Merino breeders and producers to see the progressive results of this project for themselves. The final two open days presented the sheep and the outcomes from the completion of the ten rounds of selection planned for the project. The papers in this publication offer some answers to the questions listed above.

To put the information that is contained in this publication into context, the history of the flocks and the breeding program is outlined.

History

In 1992, Merryville, Haddon Rig and East Bungaree ewes and rams were purchased from the parent studs (or on the recommendation of the parent stud in the case of the Merryville ewes). These three bloodlines were chosen because of their influence at the time in the strains that they represented (i.e. fine, medium-Peppin and broad wool strains).

They were mated in 1993 and 1994 to produce a fully pedigreed foundation flock, from which the selection lines were created in 1995. Until 1998, all selection was through the rams selected as sires within each line. Subsequently, both rams and ewes were selected. Rams were selected across three age groups while ewes were selected across six age groups. In successive years, about 30% of ewes from each line have been culled. Selection continued for a total of ten rounds, with the final drop born in 2004.

The QPLU$ Selection Lines

The Merino flock being studied within the QLPU$ Project consists of nine selection lines derived from three strains as described in Table 1.

Table 1: *The QPLU$ selection lines.*

Strain	Breeding Line	Breeding Objective
Fine	8% MP	Equal emphasis on reducing fibre diameter and increasing fleece weight.
Fine	Control	Random mating to maintain a line that represents the original population.
Medium	3% MP	Maximize increase in fleece weight and maintain fibre diameter.
Medium	8% MP	Equal emphasis on reducing fibre diameter and increasing fleece weight.
Medium	15% MP	Maintain fleece weight and maximize reduction in fibre diameter.
Medium	Industry Line	Reduce fibre diameter by 0.5 micron, increase fleece weight and improve/maintain wool quality and conformation.
Medium	Control	Random mating to maintain a line that represents the original population.
Broad	8% MP	Equal emphasis on reducing fibre diameter and increasing fleece weight.
Broad	Control	Random mating to maintain a line that represents the original population.

The selection lines named 3% MP, 8% MP and 15% MP were selected using an index of fleece weight and fibre diameter. An index allows information on more than one trait to be combined into a measure of overall genetic merit for profitability, without the need to consider each and every trait separately for all animals. The percentage figures refer to the micron premium (MP) on which they are based, which in turn reflects different emphases on fleece weight and fibre diameter. Micron premiums can also be used to describe a breeding objective in terms of likely response to selection. A ‘15% MP index’ is an index that maximises returns in a wool market that is returning 15% more for wool that is 1 micron finer.

Within each QPLU$ index selection line, rams and ewes were ranked on estimates of genetic merit across age groups, according to the appropriate index of clean fleece weight and average fibre diameter, based on all available sources of information. This information included an animal’s own performance in mean fibre diameter and clean fleece weight and the performances of its relatives through pedigree records. Adjustments were made also to the performance records to account for the influence of early environmental effects (e.g. birth type, rearing type and age) and reproduction.

Genetic merit of an animal was given by a BLUP index value, based on estimated breeding values obtained using BVEST. Sires and dams were selected on BLUP index values, based on all of the available sources of information as described above, across age groups.

The objective for the Industry line was set by the QPLU$ Industry Liaison Committee. This was a committee of ram breeders, classers and wool growers whose objective for the line was to reduce fibre diameter by 0.5 micron, increase fleece weight and improve/maintain wool quality and conformation. Selections were made by stud classer, John Williams from the Monaro Region, NSW. In the Industry Line, sheep were ranked according to an index that was developed to meet the breeding objective. John used this ranking in combination with his own visual assessment to make selections.

The Control Lines were randomly mated to represent the foundation sheep from which the first selections were made. In addition, semen from the foundation sires has been stored so that at the end of the project, the top sires produced from 10 years of selection may be compared with the starting rams.

Acknowledgements

The Trangie QPLU$ project has been possible because of the continued support of the NSW Department of Primary Industries.

We gratefully acknowledge the funding provided by Australian Wool Innovation Limited, and its predecessors, to the QPLU$ project. Additional financial assistance has been provided by Meat and Livestock Australia, the Australian Sheep Industry CRC, NSW Stud Merino Breeders’ Association Limited and Australian Wool Testing Authority Ltd.

We thank particularly the following for their efforts and commitment to the QPLU$ project:

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- Kevin Atkins and Pat Taylor are recognised for their foresight and roles in the initial development of the project and its establishment.
- Bruce Isaac, Matt Reed and Tom Snelgar for management of the QPLU$ flock, with the support of Tom Patterson, Danny Quinn and Col Gardiner in the field and Geoff Lindon, Greg Wall and Anne Mabey as Centre Managers.
- John Williams, John Cahill and Ian Evans for their classing of the QPLU$ sheep.
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- Alex Russell and Edward Joshua, together with livestock officers located around the state, in handling extension for the project.
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2006 Papers

The Trangie QPLU$ selection lines: responses in clean fleece weight and fibre diameter on completion of ten rounds of selection

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Introduction
This report summarises for Merino breeders and commercial producers the responses in clean fleece weight and fibre diameter within each of the Trangie QPLU$ selection lines on completion of the ten rounds of selection planned for the project. The responses of the 2004 drop hoggets are reported here, as well as the responses across the drops.

Responses were estimated from the average of the breeding values from the base population of each strain for clean fleece weight and mean fibre diameter of all sheep born within each line each year. The breeding value estimates are our best prediction of the genetic merit of the animals and were based on the measured performance of relatives via the pedigree and two phenotypic records of clean fleece weight and mean fibre diameter. These performances were adjusted for the effects of environmental influences. Rams were measured at around nine and 15 months of age while ewes were measured at 15 and 27 months of age.

The Trangie QPLU$ selection lines and their breeding objectives are described in the foreword to these proceedings.

Responses predicted in 2004 drop hoggets
Estimates of the predicted responses to index selection in hogget clean fleece weight and fibre diameter of 2004 drop rams and ewes for each breeding objective are presented in Table 1.

Table 1: *Predicted responses in clean fleece weight and fibre diameter for each breeding objective in 2004 drop ewes and rams after ten rounds of selection.*

Breeding objective	Clean fleece weight (%)	Fibre diameter (µm)
3% Micron Premium (MP)	17.1	0.24
8% MP	8.3	2.2
15% MP	1.3	3.05

Within each index selection line, the predicted responses in fibre diameter are as shown in Table 1. For clean fleece weight in kilograms, the predicted improvements in each index selection line of the medium wool strain are: 0.75 kg, 3% MP line; 0.37 kg, 8% MP line; and 0.06 kg, 15% MP line. Improvements of 0.29 kg and 0.42 kg in clean fleece weight were predicted for the fine wool 8% MP and 8% broad wool lines respectively.

Responses achieved in clean fleece weight and fibre diameter

Figures 1, 2 and 3 illustrate the estimates of the responses to selection in clean fleece weight and fibre diameter of hogget rams and ewes for each drop within each selected line from 1995 to 2004.

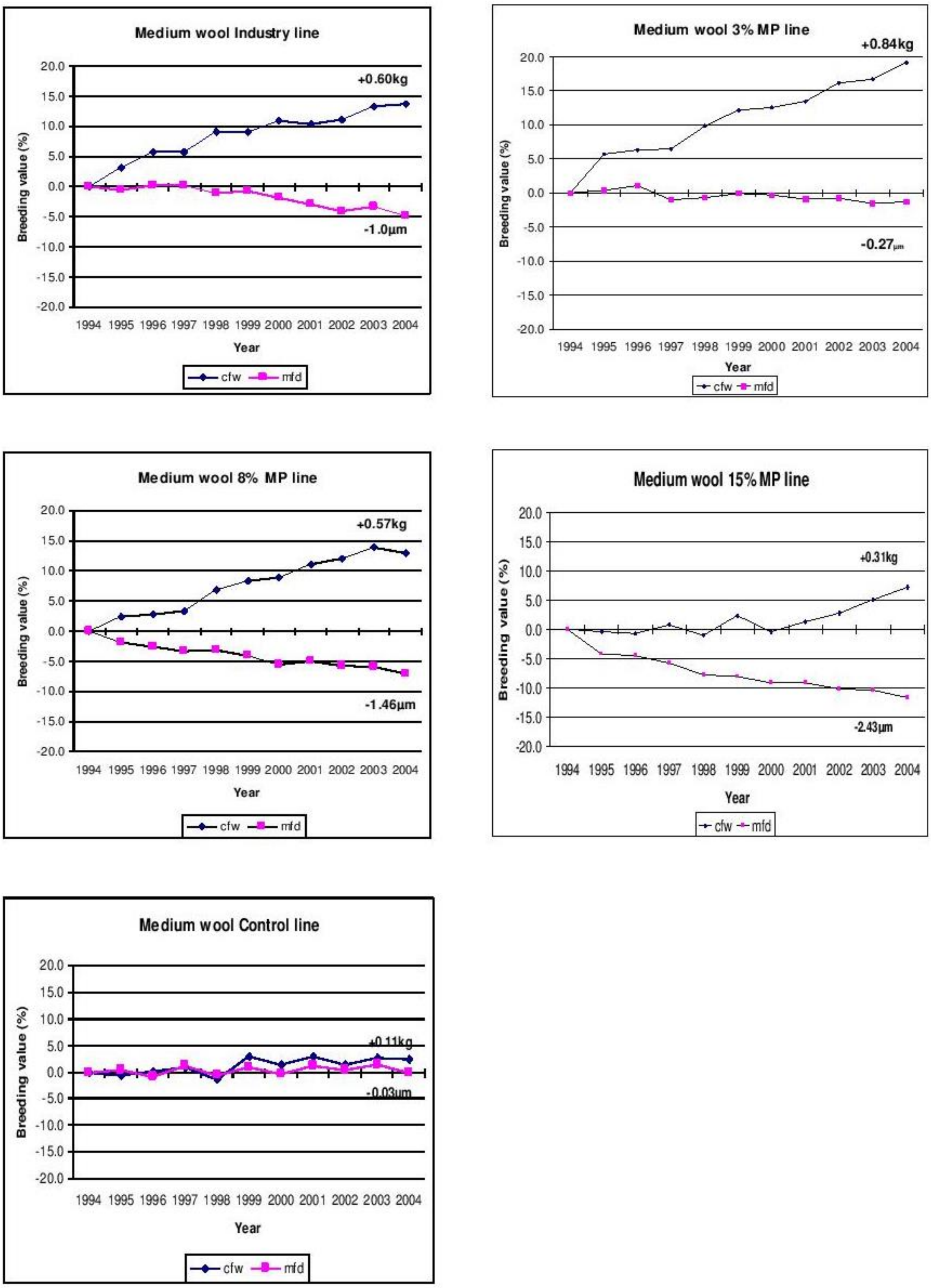

Figure 1: Improvements in clean fleece weight (cfw) and mean fibre diameter (mfd) of the QPLU$ medium wool selection lines and their control line for 1995-2004 drop hogget ewes and rams.

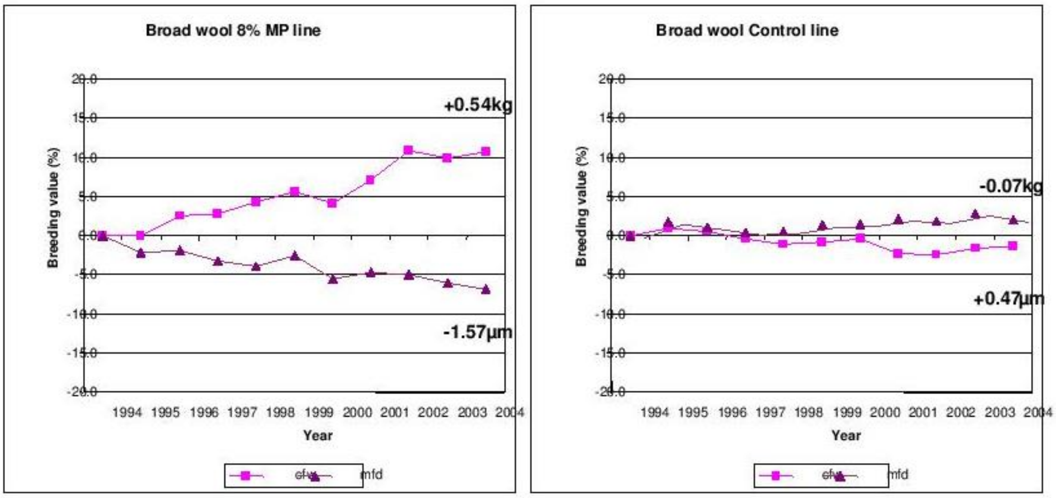

Figure 2: *Improvements in clean fleece weight (cfw) and mean fibre diameter (mfd) of the QPLU$ broad wool selection line and its control line for 1995-2004 drop hogget ewes and rams.*

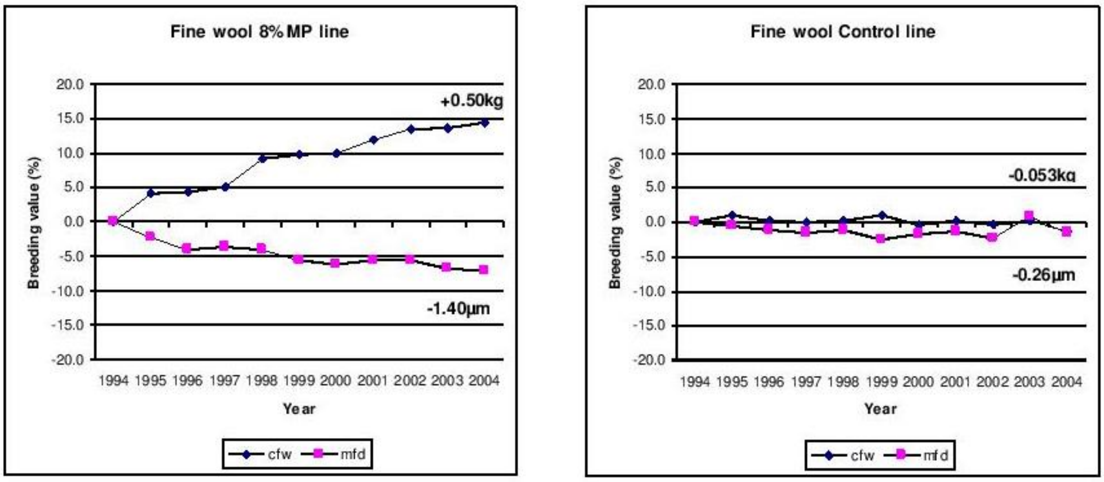

Figure 3: *Improvements in clean fleece weight (cfw) and mean fibre diameter (mfd) of the QPLU$ fine wool selection line and its control line for 1995-2004 drop hogget ewes and rams.*

Substantial improvements in clean fleece weight and/or fibre diameter have been achieved in the 2004 drop of all selected lines in accord with their prescribed breeding objectives.

For the 2004 drop hoggets of the medium wool strain, the 3% MP line (emphasis to increase fleece weight, maintain diameter) showed the largest increase in fleece weight (19.2%) with a small improvement in fibre diameter (-0.27µm). Similarly, the 15% MP line (emphasis to reduce fibre diameter, maintain fleece weight) showed the largest reduction in fibre diameter (-2.43µm) with a moderate increase in fleece weight (7.1%). The 8% MP line (emphasis to increase fleece weight, reduce fibre diameter) posted a 13% increase in fleece weight with a reduction in fibre diameter of 1.46µm.

Although the relationship between clean fleece weight and fibre diameter is unfavourable, the use of a selection index to identify sires and dams within each selected line has been able to overcome this antagonism and generate simultaneous improvements in both traits.

The 2004 drop hoggets of the Industry line (~4.5% MP index plus visual classing on wool quality and conformation) demonstrated substantial improvements in both traits (13.7% and -1.00μm). Visual classing combined with measured assessments has been effective in yielding rapid improvements in fleece weight and diameter. The visual classing used in this line has not compromised responses in fleece weight and fibre diameter.

Responses within the 8% MP lines of the fine and broad wool strains were similar to those observed in the medium wool strain with improvements in fleece weight and fibre diameter of 14.4% and 10.7% and -1.40μm and -1.57μm respectively. The ability to produce genetic changes in fleece weight and fibre diameter through the use of a selection index has been maintained irrespective of the bloodline of the base flock in which the selection has occurred. Although the fleece weight and diameter characteristics differ substantially between the bloodlines, the responses to the selection index have been consistent in size and direction across the bloodlines in the Trangie environment.

Throughout the 10 years of selection the lines have demonstrated incremental improvements in fleece weight and/or fibre diameter in accord with their predetermined breeding objectives. Generally, these improvements have been achieved with each successive drop. At the same time, clean fleece weight and fibre diameter of the control lines within each of the bloodlines have not fluctuated markedly from the values of the base population flocks used to establish the selection lines.

Overall, while improvements have been made in both fleece weight and fibre diameter in the index selection lines, the improvements in fleece weight have been larger than expected. Conversely, the improvements in fibre diameter have been less than expected in the index selection lines where fibre diameter was reduced. This may have resulted from a reduced spread of fibre diameter as the average fibre diameter of the animals within each of these selection lines was reduced.

Conclusions after ten rounds of selection

- All selection lines have demonstrated large improvements in fleece weight and/or fibre diameter in hoggets in line with predictions based on their breeding objectives.
- Traits with unfavourable genetic relationships, such as fleece weight and fibre diameter, can be improved under joint selection using a selection index. Selection for improved wool quality will not necessarily lead to reduced wool production.
- Within-stud selection can deliver predictable and rapid changes that can have commercial impact.
- Improvements in fleece weight and fibre diameter across the drops have accumulated and are permanent.
- Using a mix of visual assessment and measured performance can yield substantial improvements in fleece weight and fibre diameter.

The Trangie QPLU$ selection Lines: responses in other wool quality and production traits and fleece value.

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Introduction

The primary objective of the QPLU$ project was to demonstrate improvements in fleece weight and fibre diameter. Those improvements were presented in the preceding paper. A secondary but important objective of the project was to monitor a large number of other wool quality and production traits to determine if they changed in response to selection for fleece weight and fibre diameter so that a comprehensive evaluation of the consequences of selection could be reported. Although for many traits we have complete records from 1993 to 2004 drops, for the purpose of this paper we present the averages for the final drop of each selected and control line.

Staple length, strength and percent mid-breaks

Staple length and strength were measured on mid-side samples collected from the fleeces shorn in 2005 as part of an AWI project. Table 1 presents the results for staple length, staple strength, and percent mid-break for 670 hogget ewe fleeces. Table 2 presents the results for 900 adult ewe fleeces.

Table 1: Length, strength and percent mid-break of the 2004 drop ewes of each line.

Strain	Fine wools		Medium-Peppins					Broad wools	
Trait	**8%**	**C**	**Ind.**	**3%**	**8%**	**15%**	**C**	**8%**	**C**
Length (mm)	103	98	105	108	106	101	103	121!	115
SS (N/ktex)	31.1!	26.3	32.4	35.8	32.1	30.4	33.5	30.4	27.7
Mid break (%)	44	49	52	34!	55	58	48	17	26

! denotes a significant improvement compared to the Control line of the relevant strain. ($P<0.05$)
∀ denotes a significant deterioration compared to the Control line of the relevant strain ($P<0.05$)

Table 2: *Length, strength and percent mid-break of the breeding ewes (2000-03 drops) of each line.*

Strain	Fine wools		Medium-Peppins					Broad wools	
Trait	**8%**	**C**	**Ind.**	**3%**	**8%**	**15%**	**C**	**8%**	**C**
Length (mm)	97!	93	102	102	100	95∀	101	111	111
SS (N/ktex)	33.0!	28.2	29.8!	30.5!	24.8	24.9	25.7	30.2	29.9
Mid break (%)	51	42	32	35	38∀	34	26	34	31

! denotes a significant improvement compared to the Control line of the relevant strain. ($P<0.05$)
∀ denotes a significant deterioration compared to the Control line of the relevant strain ($P<0.05$)

Compared to the control lines of each strain, with the exception of the 15% line, we have observed increases in staple length and strength in the 2004 drop of each selected line (Table 1). These increases were significant for the selected broad and fine wool lines. There were a significantly smaller percentage of mid-breaks in the 3% line. The same general pattern was evident among the breeding ewe fleeces (Table 2) and because of larger numbers of ewes measured the differences were more often significant. Breeding ewes of the 15% line produced significantly shorter staples than the medium wool control line.

Yield and fibre diameter distribution traits

Changes in yield and statistics describing the fibre diameter distribution are given in Table 3.

Table 3: *Line averages for yield and fibre diameter distribution traits of the 2004 drop ewes.*

Strain	Fine wool		Medium-Peppin					Broad wool	
Trait	**8%**	**C**	**Ind.**	**3%**	**8%**	**15%**	**C**	**8%**	**C**
Yield (%)	62.2!	59.2	63.0	64.1	65.5	62.5	63.8	67.7!	65.1
SDFD (um)	3.6	3.8	4.3	4.3	4.2	4.1	4.4	4.7!	5.2
CVFD (%)	19.5	19.2	21.3	21.2	21.2	21.5	21.6	21.2	21.9
Comfort (100 - % > 30um)	98.6	98.4	97.0	96.9	97.1	97.2	97.1	93.5!	90.2
(% < 15um)	10.2!	5.3	5.8	4.1	7.2	11.5!	5.0	2.5	2.2

! denotes a significant improvement compared to the Control line of that strain. (P<0.05)
∀ denotes a significant deterioration compared to the Control line of that strain (P<0.05)

Both the fine and broad wool 8% lines recorded significant increases in yield of around 3% in the 2004 drop. Changes within the medium wool selected lines were smaller, variable and not significant. All selected lines showed reduced SDFD compared to their controls. The 0.5um reduction in the broad wool 8% line was the only significant difference. Changes in CVFD were generally downward but not significant. Responses in Comfort were generally small and variable. The broad wool 8% line achieved a significant improvement in Comfort compared to the broad wool control line. There were significant increases in the proportion of fibres below 15um in the two finest lines – the fine 8% and the medium 15% lines.

Style traits

Each year, hogget ewe mid-side samples were either measured (dust penetration, crimp frequency) or allocated scores according to their appearance for a number of style traits (a '0' or'1' score being best for a trait). The results for the selected and control lines of each strain are given in Table 4.

Table 4: *Line averages for style traits, fleece rot and classer grade of the 2004 drop ewes.*

	Fine wool		Medium-Peppin					Broad wool	
Trait	**8%**	**C**	**Ind.**	**3%**	**8%**	**15%**	**C**	**8%**	**C**
Dust penetration (% from tip)	44.0!	49.0	41.2	40.5	38.0!	39.1	41.0	43.8	43.7
Crimp freq. (n/25mm)	13.0!	14.9	9.5	9.5	9.7	10.6	10.1	8.4	8.5
Crimp def. (1 - 7)	3.5	3.7	3.6	3.5	3.5	3.3	3.6	3.4!	3.8
Yellowness (1 - 8)	3.7∀	2.6	5.3	5.2	5.0	4.8	5.1	6.2	6.2
Staple definition (1 - 6)	3.2!	4.1	3.1!	3.4	3.3	2.8!	3.6	2.9!	3.8
Tip shape (1 - 3)	1.7∀	1.2	1.2	1.2	1.2	1.3	1.2	1.5	1.4
Fleece rot (0 - 8)	0	0	0.3	0.3	0.1	0.1	0.3	0.1	0.1
Classer grade JW (1 – 4)	2.5	3.0	2.7	2.7	2.4	2.9	2.8	2.2!	3.1
Classer grade IE (1 – 4)	2.4	2.8	2.8	2.8	2.7	3.0	3.0	2.4!	3.0

! denotes a significant improvement compared to the Control line of that strain. ($P<0.05$)
∀ denotes a significant deterioration compared to the Control line of that strain ($P<0.05$)

Among the 2004 drop ewes, there is evidence of improvements in fleece structure and style within the selected lines regardless of strain. Staple definition improved significantly in four of the selected lines and the depth of dust penetration was significantly reduced in two lines. Crimp frequency and definition also tended to improve, significantly so for the fine and broad wool 8% lines respectively. The fine 8% line showed deterioration in tip shape and yellowness compared to the fine control. Variation in fleece rot among the lines was negligible, although the seasonal conditions experienced by this drop would have limited expression of fleece rot. The classers were generally consistent in allocating sheep from selected lines to higher grades than the control lines of each strain. Differences were significant for the broad wool strain only. Within the medium wool strain both classers tended to penalise the 15% selected line.

Carcass traits

Although it is reasonable to expect that the changes in fleece weight and fibre diameter recorded in the QPLU$ lines would have the greatest impact on attributes of the fleece, we should not discount the possibility of subtle changes in the physiology and carcass of the sheep. For the past several years, as part of a Meat and Livestock Australia project, staff from Cowra and Trangie have measured the carcasses of over 1,900 two-tooth cull rams from the QPLU$ selection lines. Preliminary results from that project are given in Table 5

Table 5: *Line averages for body weight and carcass traits of 2001-2004 drop rams.*

	Fine wool		Medium-Peppin					Broad wool	
Trait	**8%**	**C**	**Ind.**	**3%**	**8%**	**15%**	**C**	**8%**	**C**
Pre-slaughter weight (kg)	64.2	62.1	71.2!	68.6	68.4	67.9	68.1	77.9	78.5
Hot carcass weight (kg)	25.2	25.2	27.5	26.2	26.8	26.1	26.5	30.2∀	31.6
Dressing percentage (%)	38.9∀	40.1	38.5	38.0∀	38.6	38.2	38.6	38.6∀	39.9
Tissue depth GR site (mm)	8.1∀	9.4	8.3	8.5	8.5	8.7	9.1	8.9∀	10.5
Eye muscle area (cm^2)	13.5	14.0	15.6!	14.3	15.4!	14.5	14.6	15.3∀	16.1
Muscle lightness	34.2	34.6	33.2	33.8	33.5	33.4	33.8	34.4!	33.5
Muscle redness	19.6	19.5	19.5	19.1∀	19.7	19.4	19.9	20.0	19.4
pH Loin	6.0*	5.9	6.0*	6.0*	6.0*	6.0*	5.9	5.9	5.9

! denotes a significant improvement compared to the Control line of that strain. ∀ denotes a significant deterioration compared to the Control line of that strain, * denotes a significant difference from the Control line of that strain ($P<0.05$)

Rams bred within the Industry line were significantly heavier than those of the control line. Differences between the body weights of the other selected and control lines are variable, smaller and not significant. Across the range of carcass traits, differences between the selected and control lines of each strain were generally small but in some cases significant. Carcasses from the 8% broad wool line were significantly lighter in weight than the broad wool control. Across all strains, dressing percentages were slightly but significantly lower in some selected lines compared to the control lines. There was also evidence of reduced tissue depth at the GR site in all selected lines although differences were significant for the fine and broad wool strains only. Although eye muscle area was reduced in selected lines of the fine and broad wool strains, rams from two of the medium wool lines had eye muscle areas significantly larger than the control line of that strain. In terms of muscle colour, differences between selected and control lines were slight and generally not significant. The exceptions were significantly improved lightness in the broad wool selected line but significantly reduced redness in the 3% medium wool line. Loin pH was consistently and significantly higher in all selected lines of the fine and medium wool strains.

Feed intake

An important consideration in any investigation of the consequences of selection is the impact on feed intake. So far we have reported on the products of the selection lines (fleeces and carcasses). From the preceding paper we learned that wool production had increased in all selected lines and in some lines that body weight had also increased (Table 5 and 6). Has this additional production resulted from increased feed intake? The results of Sheep CRC funded research which estimated the feed intake of 670 non-breeding, adult ewes from the QPLU$ lines provides some insight. The averages of those estimates for each of the QPLU$ lines are presented in Table 6.

Table 6: *Line averages for body weight and feed intake of 1997 – 2001 drop ewes.*

	Fine wool		Medium-Peppin					Broad wool	
Trait	**8%**	**C**	**Ind.**	**3%**	**8%**	**15%**	**C**	**8%**	**C**
Live weight (kg)	61.5	62.3	68.5!	68.5!	66.7	66.8	65.6	74.2	75.8
Intake (kg DM/day)	2.12	2.09	2.43	2.18	2.29	2.38	2.23	2.34	2.53
Intake per kg LW (g/kg/day)	35.6	34.3	36.1	32.6	34.7	36.2	34.8	32.7	34.2

! denotes a significant improvement compared to the Control line of that strain. (P<0.05)
∀ denotes a significant deterioration compared to the Control line of that strain (P<0.05)

The Industry and 3% lines produced significantly heavier ewes than the medium wool control line. Differences in ewe weight between other selected and control lines were smaller and not significant. Despite differences in body weight and wool production, neither the estimates of dry matter intake per head nor per unit body weight identified any significant variation in feed intake between lines within strains. There were significant strain effects however, with ewes of the fine strain consuming significantly less per head than the medium and broad wool ewes. There were no differences between strains in feed intake per unit body weight. On that basis it is reasonable to assume that within strains the selected lines are producing heavier fleeces of finer fibre diameter for the same amount of pasture consumed as the control lines.

Fleece values

Based on improvements in fleece weight and fibre diameter reported in the preceding paper together with the additional measurements reported here (Tables 1, 3 and 4) we have most of the wool measurements required to value the 2004 drop hogget ewe fleeces with reasonable accuracy. For the purpose of valuing we assumed that the line means reported for each trait represent the true differences between the lines. By entering the line means for fibre diameter, staple strength, length, percent mid-breaks and yield into "wool cheque" an estimate of the clean price per kilogram is calculated for each line. We assumed two percent vegetable fault, and because of the extent of dust penetration, an MF6 type (Average Topmakers on the old scale) across all lines. The input data, clean prices based on the past three years of wool sales and estimated fleece values for each line are given in Table 7.

Table 7: *Line averages for hogget ewe wool valuation parameters, prices per kilogram and total fleece value per head of 2004 drop ewes.*

	Fine wool		**Medium-Peppin**					**Broad wool**	
Trait	**8%**	**C**	**Ind.**	**3%**	**8%**	**15%**	**C**	**8%**	**C**
Clean fleece weight (kg)	4.0	3.5	5.0	5.2	5.0	4.7	4.4	5.5	5.0
Mean diameter (um)	18.3	19.7	19.8	20.5	19.3	18.4	20.8	21.6	23.2
Staple strength (N/ktex)	31.1	26.3	32.4	35.8	32.1	30.4	33.5	30.4	27.7
Length (mm)	103	98	105	108	106	101	103	121	115
% Mid-break (%)	44	49	52	34	55	58	48	17	26
Yield (%)	62.2	59.2	63.0	64.1	65.5	62.5	63.8	67.7	65.1
Type	MF6	MF6	MF6	MF6	MF6	MF6	MF6	MF6	MF6
VM (%)	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Wool chq. (c/kg clean)	1088	920	932	906	1001	1071	895	872	841
$/head	43.52	32.20	46.60	47.11	50.05	50.34	39.38	47.96	42.05
$ improvement (%)	35.2	-	18.3	19.6	27.1	27.8	-	14.1	-

Based on the improvements in fleece weight and fibre diameter measured in the 2004 drop and the valuations of the wool produced for each line, the final drop of hogget ewes from the selected lines have produced fleece values that range from $5.91 (broad 8%) to $11.32 (fine 8%) above those of the control line ewes of each strain. These represent improvements in fleece value of between 14% and 35%. Ewes from the selected medium wool lines produced fleeces that ranged from around 18% to almost 28% above the value of the fleeces of control line ewes. These estimates are based on a market period of relatively low wool prices and low premiums for fine wool. The fleeces also suffered the effects of drought conditions for much of the wool growing period (high dust content, low yield and low staple strength).

Conclusions

As a consequence of the selection imposed on fleece weight and fibre diameter within the QPLU$ lines

- There were significant increases in staple length and strength in hogget and adult fleeces in a number of selected lines but a significant reduction in staple length in the adult fleece of the 15% line.
- Yield increased significantly in the fine and broad 8% lines.
- There were no significant increases in the SD or CV of fibre diameter.
- Among the style traits there were significant improvements in fleece structure (staple and crimp definition) and dust penetration but significant increases in yellowness and staple tip in the fine 8% line.

- The classers tended to favour sheep from the selected lines, significantly for the broad 8% line.

- Among the carcass traits there were significant reductions in dressing percentage, tissue depth at the GR site and muscle redness in some of the lines. There were significant increases in eye muscle area in two medium wool lines but a reduction in the broad wool line. Five of the six selected lines showed significant increases in loin pH.

- There was no evidence of change in feed intake per head or per unit body weight.

- The net effect on fleece values ranged from increases of 14 – 35%.

The costs and benefits of improving selection accuracy in Merino studs

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Maximising genetic progress (genetic improvement) in Merino breeding programs relies on accurately identifying the superior sires and dams from which to breed the next generation. Therefore, the aim of the breeder is to select those rams and ewes that have the best genes. As we cannot see a sheep's genes, we look for clues as to what those genes might be like. The best and most obvious clue is how that sheep itself performs. A heavy cutting ram is likely to have genes for high fleece weight.

However, a sheep's own performance is not a perfect indication of the performance of its genes (remember those rams that didn't "breed on"?) and it is possible to look at other clues which allow us to make an even more accurate estimation of the sheep's breeding value (the performance of its genes).

Improving Selection Accuracy

Other clues that enable us to more accurately estimate breeding value include:

- additional measurement of the animal itself at an older age (eg. two-stage selection);
- measurements of the animal's relatives (pedigree recording); and
- knowledge of the environmental effects into which the animal was born (eg. birth type, rearing type, and age of dam).

Staff at Trangie Agricultural Research Centre (TARC) have conducted an analysis of the QPLU$ flock that allowed them to calculate the accuracy of selection when varying amounts of information were taken into account. Selection accuracy was improved substantially by using two-stage selection and by using pedigree information. Generally, selection accuracy was little improved by adjusting performances for environmental effects. A more complete set of results has been presented by Mortimer et al (2001).

Improving selection accuracy translates directly to increasing rates of genetic progress. Not using additional information to improve selection accuracy reduces the rate of progress that can be made.

The Trangie QPLU$ project has shown that with a breeding program that places equal emphasis on reducing fibre diameter (FD) and increasing clean fleece weight (CFW), a medium wool Merino stud should be able to reduce FD by 0.9 microns while increasing CFW by 10.4%, over a ten year period. These results could be achieved without the introduction of outside genetics and allowing for 25% of sheep to be classed out on visual assessment.

However, these figures rely on the stud using all possible sources of information to estimate breeding value (i.e. high selection accuracy). These sources being: two stage measurement of rams and ewes, pedigree recording and adjustment for early life environment effects.

The Trangie QPLU$ project involves many different breeding lines, one of which is a medium-wool line that places equal emphasis of FD and CFW. Figure 1, below, shows the improvement in FD and CFW that was achieved in that line over ten years of selection. It also shows the range of improvement that can be expected in Merino studs that place equal emphasis on FD and CFW but use varying amounts of information, and therefore achieve varying levels of selection accuracy.

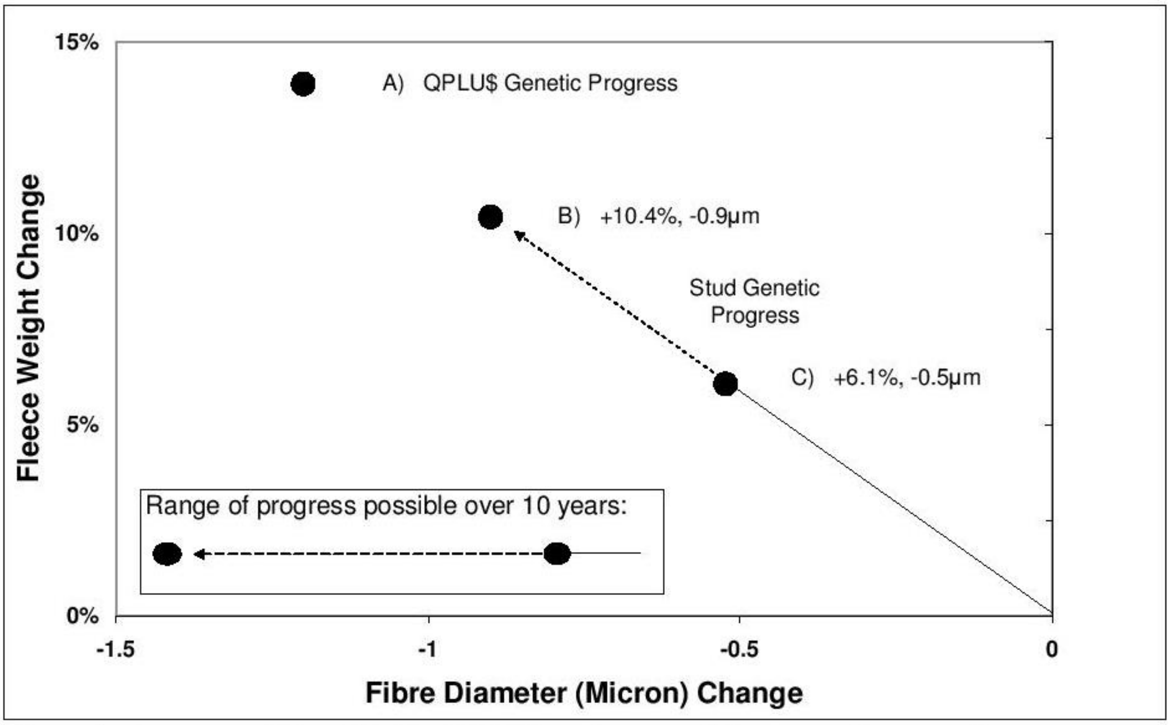


Figure 1: *Progress achieved in the QPLU$ project over 10 years and range of progress possible in a Merino stud over the same period.*

The difference between the QPLU$ genetic progress (point A) and the "maximum" stud genetic progress (point B) is that in the case of the stud, some emphasis is placed on visual assessment (25% in this case), whereas selections in the QPLU$ project are based almost entirely on measurement. The difference between the "maximum" stud genetic progress and the "minimum" stud genetic progress (point C) is a result of the selection accuracy achieved.

Costs and Benefits of Improving Selection Accuracy

In order to quantify the costs and benefits of improving selection accuracy, we will discuss here a ram breeding flock consisting of 1000 stud ewes. From these 1000 stud ewes, 375 rams are weaned and 250 rams are able to be sold. As per the scenario above, the minimum amount of genetic progress achieved by this stud over 10 years is a reduction in FD of half a micron and an increase in CFW of 6.1%. This is achieved by measuring rams once at 10 months of age and ewes once at 16 months of age.

The maximum amount of genetic progress that this stud could achieve, allowing for 25% of sheep to be classed out on visual assessment, is a reduction in FD of 0.9 microns and an increase in CFW of 10.4% over ten years. This higher rate of genetic progress would be achieved by measuring rams at 10 and 16 months of age, measuring ewes at 16 months of age and at their first adult shearing, recording pedigree and recording early life environment effects.

Following is a discussion of the incremental costs and benefits of each level of information use and selection accuracy.

1. Single stage measurement – rams measured at 10 months and ewes at 16 months of age

At TARC, lambing occurs from mid June to the end of July and all lambs are shorn as weaners at the start of the general shearing in September. No information is collected at this point and this shearing is not necessary from the point of view of improving selection accuracy. The QPLU$ rams are shorn in April at 10 months of age and the hogget ewes are shorn during the general shearing in September.

Fleeces are weighed and side samples are collected over the board during these shearings. The side samples are submitted for measurement and the measurements are forwarded to Advanced Breeding Services who produce a selection report which includes estimated breeding values for each of the traits measured, along with an index score and rank for each sheep.

Costs

Rams are typically shorn at 10 months of age to prepare them for sale as hoggets, so the cost of collecting the measurements at this point is the labour required over and above normal shearing. The QPLU$ rams' fleeces are weighed and side samples collected over the board at shearing. This process requires three extra people for the duration of the ram shearing. For 375 young rams, this would be three people for one day.

Some breeders prefer to collect side samples prior to shearing and this would require an additional mustering of the young rams. The labour required to side sample the rams prior to shearing would be two or three people for one day. In this case one additional person would be required at shearing to weigh fleeces. The extra labour required to collect the measurements on hogget ewes is the same as for the 10 month old rams. The total cost of additional labour is about six days labour at $20/hr (including superannuation and worker's compensation insurance), or approximately $960.

The cost of measuring the side samples would be approximately $2.50 per sheep (including yield), or $1875 for 750 progeny. The cost of having these measurements processed to produce a selection report would be approximately $115 for 750 progeny (price quoted by Advanced Breeding Services). This gives a grand total of $2950. If 250 rams are sold, this works out to be $11.80 for every ram sold.

Benefits
Single stage measurement gives a level of selection accuracy that can achieve improvements in FD and CFW of half a micron and 6.1% over 10 years, in the scenario described here. This is without the benefit of introducing outside genetics. So, for a cost of $11.80 per ram sold, the stud can achieve a rate of genetic progress that will see FD reduced by half a micron in ten years and CFW increased by 6.1%. Most Merino studs already invest in collecting FD and FW information. Achieving this level of progress would depend on how well this information is used.

2. Single stage measurement plus pedigree recording

Pedigree is determined at TARC by single sire joining all rams, by lambing ewes down in sire groups and by mothering up all lambs on the day of birth. This process requires many small paddocks to be used for joining and lambing, 72 paddocks in the case of the QPLU$ project. The ewes are drafted into sire groups prior to joining. The rams are fitted with raddle harnesses and the colour of the crayon is changed half way through joining so that infertile rams can be identified and replaced.

Prior to lambing the ewes are once again drafted into their sire groups so that sire pedigree can be recorded. The ewes are also side branded (using Si-Ro-Mark) with their tag number so they can be identified from a distance during lambing. Each morning during lambing, every lambing paddock is checked and any new lambs are caught, tagged and have their mothers tag number recorded, so that dam pedigree can be recorded.

Costs
The cost of recording full pedigree (both sire and dam) is quite high. The system used at TARC has high labour and infrastructure costs but there are alternatives that involve much less labour and fewer paddocks.

DNA fingerprinting requires that a blood sample be collected from all ewes, rams and progeny in the first year and all progeny in subsequent years. Drops of blood are collected on special absorbent cards and submitted for analysis. The advantages include a lower labour cost and a lower infrastructure cost as rams can be joined in syndicates. DNA fingerprinting currently costs around $12.50 per sample. For the scenario discussed here, this would amount to $12.50 x 1800 in the first year and around $12.50 x 750 thereafter. In addition, the labour required to collect the samples would involve two people sampling around 25 sheep per hour, including the time taken to check tag numbers and samples. The cost in the first year would be around $25380 and around $10575 thereafter. This would give an ongoing cost of $42.30 per ram sold.

A new system with the promise of further lowering the cost of pedigree recording is called Pedigree Matchmaker. This system is used to collect dam pedigree. Sire pedigree would require single sire joining. Pedigree Matchmaker works on the principle that lambs follow their mothers closely. All ewes and lambs are tagged with an electronic tag (at lamb-marking for example) and a tag reader is mounted in a race leading to a fenced off watering point. Computer software records which lambs follow which ewes and over a period of time is able to allocate dam pedigree. The system is still being tested however it is believed that the accuracy will be similar to that of manual pedigree recording. The initial cost of the equipment and software required would be in the order of $20000 for 1000 ewes but the ongoing cost would be much less, negligible if the tags are re-used.

A survey of Merino studs conducted by Barnett (1998) indicated that the average cost of recording full pedigree is $4.71 per lamb born. However this does not take into account the considerable costs of erecting and maintaining the many lambing paddocks required for single sire mating and lambing. More recently, several stud Merino breeders have indicated that their cost of collecting dam pedigree is about $10 per lamb born (C Pope 2006, pers. comm.). For the scenario discussed here, this would be about $8000, or $32 per ram sold. This does not include the cost of infrastructure and may not value labour at commercial rates. For this discussion, the cost of pedigree recording will be based on DNA fingerprinting at $42.30 per ram sold. In addition the cost of processing the data would increase by $262.55, or $1.05 per ram sold, giving a total of $43.35 per ram sold.

Benefits
Figures 2 and 3 show the incremental improvements in genetic progress achieved by increasing levels of selection accuracy. You can see that the addition of full pedigree information increases the improvement in FD by 0.1 microns (to -0.6 microns) over ten years and CFW by 1.2% (to 7.3%) over ten years. These improvements come at a cost of around $42.30 per ram sold, not including infrastructure.

3. Two stage measurement

While a single measurement of a sheep's performance will give a good indication of its genetic merit, a second measurement at an older age will improve selection accuracy. At TARC the second stage measurement takes place at the general shearing in September. Rams are 16 months of age and ewes are 28 months of age.

Costs
At TARC the cost of measurement is about the same as for the first stage measurement. There is the opportunity to reduce costs by classing out some sheep on the basis of their first stage measurement. For example, there would be no loss of accuracy if only 250 rams and ewes were measured.

Perhaps the greatest barrier to the use of second stage measurement is the fact that ram breeders usually want to sell their rams at roughly 16 months of age and clients will want these rams to have wool on them. Shearing them to measure fleece weight at 16 months therefore presents a significant problem.

The additional cost for measurement and analysis of 500 sheep is around $2285 or $9.14 per ram sold, compared with single stage measurement only.

Benefits
As shown by Figures 2 and 3, the benefit of a second stage measurement is an additional reduction in FD of 0.2 microns (to -0.7 microns) over ten years and an

additional increase in CFW of 2.1% (to 8.2%), compared with single stage measurement.

4. Two stage measurement plus full pedigree

Costs
Based on the costs described above, the additional costs of a second stage measurement and recording full pedigree would be $12860. The cost of processing would rise by $489, giving a total of $13349, or $53.40.

Benefits
Compared to single stage measurement, the increase in selection accuracy will result in an additional reduction in FD of 0.4 microns (to -0.9 microns) over ten years and an additional increase in CFW of 4.1% (to 10.2%) over ten years.

Figure 2: *Reduction in fibre diameter possible over ten years, using increasing amounts of performance information.*

Costs of collecting information are expressed in dollars per ram sold. Amounts in brackets show increase in cost over that of 1st stage measurement.

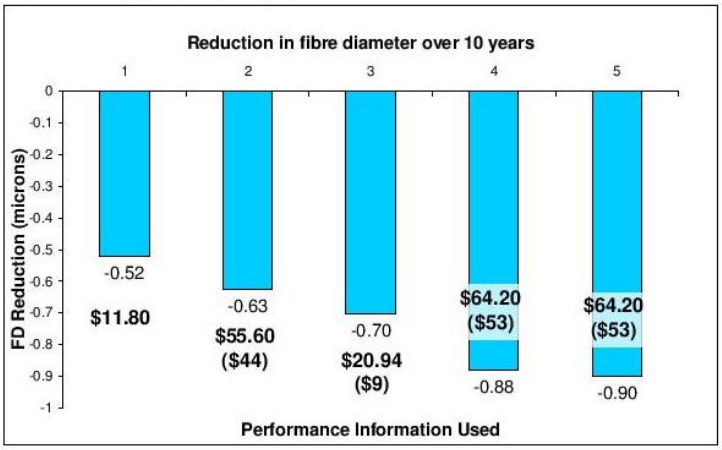
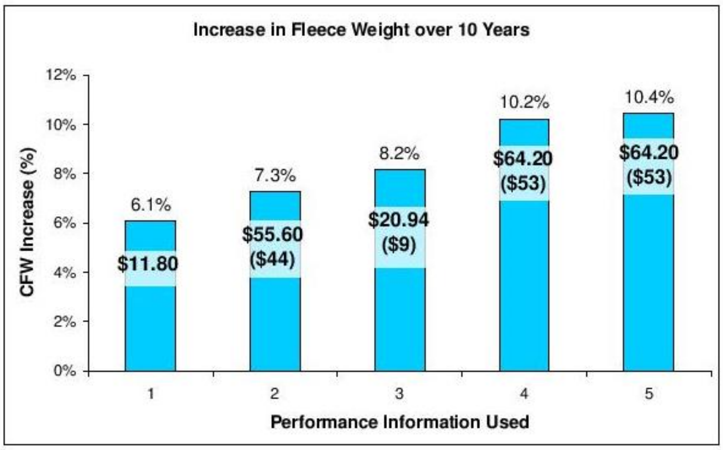


Figure 3: *Increase in clean fleece weight possible over ten years, using increasing amounts of information.*



5. Two stage measurement plus full pedigree plus early life environment

A lamb's environment in its early life can have an impact on how it performs at measurement, especially at first stage measurement, when it is still getting over any set-back it had as a lamb.

It is possible to make adjustments for these early life environment effects, it they are recorded. They include whether a lamb was born as a single or as a twin, whether it was reared as a single or as a twin, whether it was born early or late in the drop and whether its mother was a maiden or adult ewe. Obviously, a lamb born and reared as a twin is worse off than one born and or reared as a single. Those born early in the drop will be older when measured and those born to adult ewes will have higher birth weights and be better nourished than those born to maiden ewes.

At TARC, early life information is collected when lambs are being mothered up. Both birth weight and birth status (single or twin) are recorded at this time. It is possible to make an adjustment for early life environment based on a body weight collected at weaning. This is because there is a very strong relationship between weaning weight and early life environment (Atkins and Ramsay, 2001). Factors such as date of birth, birth status, rearing status and age of dam account for much of the differences seen in body weights at weaning.

Costs

If pedigree is recorded manually (by mothering up lambs), early life environment information may not add significantly to the cost of pedigree recording as it is usually collected at the same time that lambs are being mothered up. In the case of collecting pedigree from DNA finger-printing, weaning weight can be used to make the adjustments at little additional cost. For the purposes of this discussion no additional cost is associated with adjustments for early life environment.

Benefits

Compared with single stage measurement only, the increase in selection accuracy given by two stage measurement with full pedigree and adjustments for early life environment will result in an additional reduction in FD of 0.4 microns (to -0.9 microns) over ten years and an additional increase in CFW of 4.3% (to 10.4%) over ten years.

Adjustments for early life environment improve accuracy of selection for CFW more than they do for FD. This is because CFW is affected more by early life environment than FD. In a situation where a second stage measurement is not possible, early life adjustments would give a greater improvement than that shown here.

Effects on Stud Clients of Improving Selection Accuracy in Merino Studs

The rate of genetic progress achieved by a client of any given Merino stud will be the same as that of the stud itself. Therefore, if a Merino stud has been using all available performance information and is reducing FD by 0.9 microns in ten years, that stud's clients will find that their clip will become 0.9 microns finer over the same period. This of course assumes that the client buys rams of the same standard from year to year.

We have shown that the marginal cost of improving genetic progress from –0.5 microns and +6.1% CFW over ten years to –0.9 microns and +10.4% CFW over the same period, would be of the order of $53 per ram sold, in a 1000 ewe stud.

If this cost was passed on to the client, they would be paying $53 per ram bought to improve their FD by an additional 0.4 microns and their fleece weight by an additional 10.4% every ten years. For a client with 2000 ewes, replacing eight rams each year, the increased cost of rams would be $424. For 2000 21μm ewes, the gross margin (GM) would be approximately $96000 per year (http://www.agric.nsw.gov.au/reader/livebud). Increasing the fleece weight by 1% per year (10.4% over 10 years) would increase GM by $671. The increase in GM flowing from the extra reduction in FD and increased value of surplus sheep would be additional.

Conclusion

This paper has examined a scenario where the stud placed roughly equal emphasis of CFW and FD. Mortimer et al (2001) conducted the same exercise for breeding objectives that place more emphasis on either FD or CFW. It has been shown that for breeding objectives that place more emphasis on fleece weight rather than fibre diameter, the improvements in genetic progress achieved by improving selection accuracy are greater. This is because FD is more strongly inherited than FW. Ironically, it is more difficult for a stud to get a 2nd stage measurement of FW, due to the pressure to sell young rams with wool on them.

The aim of this paper has been to estimate the costs of collecting the additional information required to improve selection accuracy and the benefits gained in terms of increased rates of genetic progress. The costs used in this paper rely on many assumptions and may not accurately reflect any one Merino ram breeding operation. It is hoped that this analysis will give readers some idea of the likely costs and benefits associated with investing in improved selection accuracy. It is also hoped that sufficient detail has been given for readers to determine how their own cost structures might change the costs quoted here.

We have shown that the benefits of increased selection accuracy, and therefore improved genetic progress, will be largely expressed in the client flocks of the stud. These benefits are substantially greater than the additional costs required by the stud for that improved accuracy. For the stud itself the value in improving the rate of genetic progress will be realised in a higher value wool clip and may be realised in improved ram sales. However in the current environment, the value may simply be in maintaining ram sales at current levels in the face of increasing competition from other Merino studs and other sheep breeds.

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An Interview with John Williams – Classer of the QPLU$ Industry Line

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- John Williams has worked in the Australian merino industry for 57 years: for the past 27 as a professional sheep classer.
- Prior to becoming a professional classer John had extensive stud experience with his family's Manderley Merino Stud.
- Based at Cooma in the heart of Australia's renowned Monaro region, John services an extensive clientele of merino studs across Australia and New Zealand.
- John's involvement with the QPLU$ project commenced in 1994 when he was invited to become one of the two classers who would annually 'class' ALL sheep bred in the QPLU$ selection lines. Through this annual assessment, the effect of index (only) selection in the other lines would be tracked.
- John's other role, and one that provided him with a great deal of satisfaction, was to select and direct the breeding of the "Industry Line" within the medium wool sheep. John had total control over the selection of both ewes and rams (after the initial establishment years), and the allocation of matings.
- A number of studs classed by John have been prominent in wether trials and he has had a long association with (former) Cooma based Department of Agriculture sheep and wool officer, John Cahill. John Cahill also served the project as the second classer for visual assessment of all lines, from its' inception until his retirement in 2001.
- John Williams sees the three main strains, the fine, medium and broad wool's as representing the broader Australian industry, well beyond central NSW where the project is based.
- He came to the project with no preconceptions about any of the strains involved and a strong intention to take them at 'face value' and see what gains could be made with the range of selection strategies involved.
- The objective for the Industry Line was to reduce fibre diameter by 0.5 micron whilst maximising fleece weight gain and either maintaining or improving the main visually assessed characters. This has been readily achieved with a ***reduction*** of 1.0 micron in FD breeding value, and an ***increase*** in Clean Fleece Weight breeding value of 0.6 kg or 13.7%
- The balance between visually assessed and measured traits is often subject to much discussion. John's strategy for the industry line is relatively straightforward. That is to get the maximum gain possible, using a combination of visual and measured traits.
- John has used a combination of visual selection and measured traits combined into an index in the selection of the industry line.
- The objectives for visual traits can be summarised as:
    1. Maintain body size under the conditions that existed.
    2. Select for long deep bodies with a good spring of rib.
    3. Moderate frontal development.
    4. Feet and legs functional and satisfactory.
    5. Structurally satisfactory in other regards.

6. Sufficient lock structure and nourishment to protect the fibre against the conditions as much as possible. In the main these objectives have been achieved.

Whilst John has been selecting and directing the breeding of the Industry Line, the other lines have been selected entirely based on their performance in measured traits compiled into various indexes. They are the 3%, 8% & 15% micron premium indexes, plus a control line, in the medium wool strain; and an 8% and a control line in each of the fine and broad wool strains.

So, what has John seen happening in the other lines, where visual selection has not been applied?

- Nothing extraordinarily bad.
- However 10 years – with really only 8 effective years of selection – is not very long in merino breeding. Another 5 years might have been revealing.
- Changes in wool type – particularly tip and lock structure – are the most evident. Particularly in the 15% line.
- The 3% line, with its heavy emphasis on fleece weight, is (logically) at the other end of the scale, and is becoming an extremely heavily developed line.
- The 8% line(s), with their (roughly) equal emphasis on micron reduction and fleece weight increase, are an interesting group. There appears to be some divergence WITHIN these lines. That is, there are some sheep within this group displaying the characteristics of the heavy cutting line, and others displaying the traits of the lower(ed) fibre diameter line.

- Overall they are a very good line of sheep.

Take Home Messsage

- **It's not rocket science!**
- **You get what you select for.**
- **Have an objective in mind and then work as hard as you can towards it.**

A comparison of changes in production and wool quality in later drops of QPLU$ hogget and breeding ewes

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Introduction

During the course of the QPLU$ breeding program we have provided regular updates on the progress of the various selection lines. To date these have largely been based on the changes observed in successive drops of hogget ewes and rams and the wool and carcasses they produced since selection began in 1995. Given that in most self replacing flocks this age group accounts for only 20% of total flock production, it is obviously important to determine how closely the changes observed in the hoggets of each selection line are reflected by the production and wool quality of their adult contemporaries. This paper compares and contrasts the changes observed in a large number of wool quality and production traits in the final (2004) drop of hogget ewes with that of mixed age breeding ewes of each selection line. We also report on differences between the lines in some of the components of reproduction. To that end we compare the production and wool quality of all 2004 drop ewes (n = 670) with a random sample of 900 mixed age ewes born between 2000 and 2003 inclusive. The data is based on each ewe's production records and fleece samples collected during 2005. The reproduction data includes the adult (3-5 years of age) performance of all breeding ewes born between 1999 and 2002.

Improvements in fleece weight and fibre diameter and changes in body weight

Hogget and adult responses in clean fleece weight, mean fibre diameter and body weight are shown in Table 1.

Table 1 Clean fleece weight, mean fibre diameter and body weight of the 2004 drop (h) and mixed age adult ewes (a) of each line

Strain		Fine wool		Medium wool					Broad wool	
Trait		**8%**	**C**	**Ind.**	**3%**	**8%**	**15%**	**C**	**8%**	**C**
Clean fleece weight (kg)	h	3.9✔	3.3	5.0✔	5.4✔	5.1✔	4.7✔	4.5	5.8✔	5.0
	a	4.4✔	3.4	5.4✔	5.4✔	5.4✔	4.9	4.7	6.0✔	5.0
Mean fibre diameter (µm)	h	18.1✔	19.2	19.5✔	20.1✔	18.7✔	17.7✔	20.4	21.4✔	24.1
	a	19.4✔	20.3	20.9✔	21.3✔	20.3✔	18.9✔	22.0	23.0✔	25.4
Body weight (kg)	h	48.7✔	46.8	53.1✔	51.9✔	53.0✔	50.6	49.7	58.7✗	60.7
	a	55.6	55.7	62.2✔	61.7✔	60.6✔	59.7	57.7	68.4	67.9

✔denotes a significant improvement compared to the Control line of the relevant strain. (P<0.05)
✗denotes a significant deterioration compared to the Control line of the relevant strain (P<0.05)

Compared to the control lines of each strain the hogget fleece weights and fibre diameters have all shown significant improvements in accord with the breeding objectives of each selection line. Among the medium wool lines increases in fleece weight ranged from 0.9kg for the 3% MP line to 0.2kg for the 15% MP line. The increases in fleece weight for the selected broad and fine wool lines were 0.8kg and 0.6 kg respectively. Similarly, reductions in fibre diameter among the medium wools ranged from 2.7µm for the 15% MP line to 0.3µm for the 3% MP line. The reductions in fibre diameter of the selected broad and fine wool lines were 2.7µm and 1.1µm respectively. These are generally consistent with the hogget responses based on breeding values reported in 2006. Although for both traits the performance of the adult ewes of each line closely follows the pattern of response observed in the hoggets, adult ewes of the selected lines often expressed larger increased in fleece weight relative to the adult control ewes. Proportionally larger reductions in fibre diameter were also observed in adults of three of the medium wool selected lines (Industry, 3% and 15% MP).

Several of the selected lines recorded small but significant increases in hogget and adult body weight compared to the controls of each age group. These included the Industry, 3% and 8% MP lines of both age groups. Increases in body weight were expected in the Industry line for which selection was imposed on size and physical conformation as well as breeding values for fleece weight and fibre diameter. The significant body weight advantage of the selected fine wool and deficit of the selected broad wool hoggets was not evident among the adult ewes of those lines.

Staple length, staple strength and percent mid-breaks

Staple length and strength were measured on mid-side samples collected from the fleeces shorn in 2005. Table 2 presents the results for staple length, staple strength, and percent mid-break for hogget and adult ewe fleeces.

Table 2 Length, strength and percent mid-break of the 2004 drop (h) and mixed age adult ewes (a) of each line

Strain		Fine wool		Medium wool					Broad wool	
Trait		8%	C	Ind.	3%	8%	15%	C	8%	C
Length (mm)	h	103	98	105	108	106	101	103	121✔	115
	a	97✔	93	102	102	100	95✖	101	111	111
SS (N/ktex)	h	31.1✔	26.3	32.4	35.8	32.1	30.4	33.5	30.4	27.7
	a	33.0✔	28.2	29.8✔	30.5✔	24.8	24.9	25.7	30.2	29.9
Mid break (%)	h	44	49	52	34✔	55	58	48	17	26
	a	51	42	32	35	38✖	34	26	34	31

✔denotes a significant improvement compared to the Control line of the relevant strain. ($P<0.05$)
✖denotes a significant deterioration compared to the Control line of the relevant strain ($P<0.05$)

Given the increases in fleece weight in all selected lines presented in Table 1 we might also anticipate increases in staple length – an important component of fleece weight. Among all selected lines other than the 15% MP line the hogget ewes grew wool staples 2 – 6 mm longer than their unselected controls. The only significant increase was that of the selected broad wool line. Other than for the selected fine wool line these increases in staple length largely disappeared in fleeces of the breeding ewes. In fact in this age group breeders of the 15% MP line produced wool significantly shorter (6mm) than the medium wool controls.

Differences in staple strength between the selected and control line hogget ewes of each strain were generally small and not significant. The exception was for the selected fine wool line which produced wool staples 4.8N/Ktex stronger than the controls of that strain. A significant increase of the same magnitude was also evident in the breeding ewes of this line. The adult ewes of two of the medium wool selected lines (Industry and 3% MP) also produced significantly stronger staples than the medium wool controls. Differences between selected and control line hoggets in the proportion of mid breaks were variable and only significant for the 3% MP line. Across all selected lines the adult ewes tended to produce wool with a higher proportion of mid breaks than the control ewes. This was significant for the 8% MP line.

Yield and fibre diameter distribution traits

Changes in yield and statistics describing the fibre diameter distribution are given in Table 3.

Table 3 Line averages for yield and fibre diameter distribution traits for 2004 drop (h) and mixed age (a) ewes

Strain		Fine wool		Medium wool					Broad wool	
Trait		8%	C	Ind.	3%	8%	15%	C	8%	C
Yield (%)	h	62.2✔	59.2	63.0	64.1	65.5	62.5	63.8	67.7✔	65.1
	a	66.2✔	61.1	66.3	68.2✔	68.6✔	65.1	65.5	70.2✔	67.3
SDFD (um)	h	3.6	3.8	4.3	4.3	4.2	4.1	4.4	4.7✔	5.2
	a	4.0	4.0	4.5✔	4.7	4.4✔	4.1✔	4.8	4.8✔	5.2
CVFD (%)	h	19.5	19.2	21.3	21.2	21.2	21.5	21.6	21.2	21.9
	a	20.6✘	19.6	21.4	22.0	21.9	21.9	22.0	21.0	20.4
Comfort (100 - % > 30um)	h	98.6	98.4	97.0	96.9	97.1	97.2	97.1	93.5✔	90.2
	a	98.3	98.1	96.8✔	95.8	97.1✔	98.1✔	95.0	93.4✔	85.0
(% < 15um)	h	10.2✔	5.3	5.8	4.1	7.2	11.5✔	5.0	2.5	2.2
	a	6.8✔	3.4	3.6	2.9	5.3✔	9.5✔	2.7	1.5	0.8

✔ denotes a significant improvement compared to the Control line of that strain. ($P<0.05$)
✘ denotes a significant deterioration compared to the Control line of that strain ($P<0.05$)

Both the fine and broad wool 8% lines recorded significant increases in yield of around 3% and 3-5% in the hogget and adult fleeces respectively. Significant increases in yield of around 3% were also evident in adult fleeces of two of the selected medium wool lines (3%MP and 8%MP). In accord with reductions in mean fibre diameter (Table 1), the standard deviation of diameter (SDFD) was also reduced in most selection lines compared to control line fleeces. Although consistent across the lines, these reductions were larger and more often significant in the adult fleeces than the hoggets. Because the mean and standard deviation of fibre diameter have both declined in the majority of selected lines the ratio of both traits CVFD shows little evidence of change in either age group. The exception was the selected fine wool adults which lost 0.9µm in mean diameter (Table 1) but showed no change in SDFD. As a consequence the CVFD of that line increased significantly by one percent. Although the proportion of fibres above 30µm shows little change in the hogget ewes other than for the selected broad wools, this trait improved significantly in adult fleeces of four of the selected lines. At the other end of the fibre diameter distribution the proportion of fibres less than 15um also improved significantly in the selected fine wool line and the 8% MP and 15% MP medium wool lines.

Style traits

Hogget and adult ewe mid-side samples were either measured (dust penetration, crimp frequency) or allocated scores according to their appearance for a number of style traits. The results for the selected and control lines of each strain and age group are given in Table 4.

Table 4 Line averages for style traits and classer grade of the 2004 drop (h) mixed age (a) ewes

		Fine wool		Medium wool					Broad wool	
Trait		**8%**	**C**	**Ind.**	**3%**	**8%**	**15%**	**C**	**8%**	**C**
Dust penetration (% from tip)	**h**	44.0✓	49.0	41.2	40.5	38.0✓	39.1	41.0	43.8	43.7
	a	45.8✓	53.5	38.4	38.1	36.2✓	39.3	38.7	40.1	42.0
Crimp frequency (n/25mm)	**h**	13.0*	14.9	9.5	9.5	9.7	10.6	10.1	8.4	8.5
	a	13.2*	15.7	10.1	9.6	9.8	10.7*	10.0	8.5	8.7
Crimp definition (1✓- 6)	**h**	3.5	3.7	3.6	3.5	3.5	3.3	3.6	3.4✓	3.8
	a	3.0	3.0	3.3✓	3.4✓	3.2✓	3.0✓	3.6	3.2✓	3.6
Greasy colour (1✓- 8)	**h**	3.7✗	2.6	5.3	5.2	5.0	4.8	5.1	6.2	6.2
	a	2.7✗	2.0	4.3	4.1	4.4✗	4.4✗	4.0	4.6	4.9
Staple definition (1✓- 6)	**h**	3.2✓	4.1	3.1✓	3.4	3.3	2.8✓	3.6	2.9✓	3.8
	a	3.1✓	3.4	3.3✓	3.5	3.3✓	2.9✓	3.7	3.5✓	3.8
Tip shape (1 - 3)	**h**	1.7*	1.2	1.2	1.2	1.2	1.3	1.2	1.5	1.4
	a	1.0	1.0	1.1	1.1	1.1	1.1	1.1	1.4*	1.2
Classer grade (1✓ – 4)	**h**	2.5	3.0	2.7	2.7	2.4	2.9	2.8	2.2✓	3.1
	a	2.0✓	2.9	2.0✓	2.0✓	2.1	2.3	2.4	1.8✓	2.8

✓ denotes a significant improvement compared to the Control line of that strain. (P<0.05)
✗ denotes a significant deterioration compared to the Control line of that strain (P<0.05)
* denotes a significant difference from the Control line of that strain (P<0.05)

As reported in past years for hogget ewes, a number of style traits have improved in several lines as a consequence of long-term selection for fleece weight and fibre diameter. These included the Industry line for which sires and dams were selected on visual assessment as well as breeding values for fleece weight and fibre diameter and in other lines that were selected only on breeding values. The traits that showed evidence of significant improvement were dust penetration, crimp definition and staple definition. In general the improvements observed in hogget fleeces were also evident and more often significant in the breeding ewe samples of each line. We did detect some deterioration in the colour of the fleece samples in three of the selected lines (Fine 8%, Medium 8% and 15%) which was not apparent in the hogget fleeces of those two medium wool lines. In contrast there was a non-significant improvement in colour in the selected broad wool adult ewes but not the hoggets of that line. The increases in colour were slight in the medium wool lines but larger in the selected fine wool ewes of both age groups. Even so the colour of the selected fine wools was significantly better than that of the other two strains and unlikely to attract discounts at valuation compared to fine wool control line fleeces. Changes in the fine wools were in the range of shades of white while those in the medium wools were in the range of cream rather than yellow. Although the impact on medium wool values is uncertain at this stage, it is more likely to result in a few extreme fleeces being classed out rather than down-grading of the main fleece lines. We also detected significant changes in crimp frequency in two selected lines. Although there was a trend for the higher fleece weight lines to produce lower crimp frequencies than controls this was only significant in both age groups of the fine wool strain. In contrast the selection emphasis on fibre diameter in the 15% MP line has increased crimp frequency relative to controls, significantly so for the adult ewes of that line. Staple tip shape showed almost no variation in either age group of the medium wool lines. In the other two strains it tended to increase in the selected lines, significantly for the fine wool hoggets and broad wool adults respectively.

On balance the net improvement in the style of the fleece wool produced by the majority of selected lines together with small increases in body weight in some lines (Table 1) has probably contributed to the significant improvement in John Williams' assessment of overall visual merit as indicated by improved average classer grade. These improvements were more often significant in the adult than the hogget ewes. As reported previously, despite significant improvements in staple and crimp definition, the shorter, lighter cutting fleeces produced by the 15% MP line failed to attract improved average classer grades compared to the unselected control line ewes of that strain.

Reproduction

An evaluation of the impact of selection on the production of the breeding ewes of each line would be incomplete without consideration of their reproductive performance. The traits analysed cover the fertility, fecundity, lamb survival and weaning percentage of ewes bred within the selected and control lines of each strain. Table 5 presents estimates of these components of reproduction based on the adult performance of ewes born between 1999 and 2002.

Table 5 Line averages for components of reproduction 1999 – 2002 drop ewes

	Fine wool		Medium wool					Broad wool	
Trait	**8%**	**C**	**Ind.**	**3%**	**8%**	**15%**	**C**	**8%**	**C**
Ewes lambing/ewe joined (%)	74	74	85	85	85	88	85	73	77
Ewes twinning/ewe joined (%)	33	36	50	50	46	50	47	43	48
Lambs born/ewe joined (%)	108	110	137	136	132	138	134	119	129
Lamb survival/lamb born (%)	66✕	78	75	72	70✕	76	76	71	76
Lambs weaned/ewe joined (%)	70✕	84	102	95	91✕	104	100	82✕	96

✓ denotes a significant improvement compared to the Control line of that strain. ($P<0.05$)
✕ denotes a significant deterioration compared to the Control line of that strain ($P<0.05$)

Although there were significant differences in conception rate between the strains, differences between selected and control lines within strains were smaller and not significant. This observation also applied to the proportion of ewes bearing multiple lambs. Although not significant, the selected broad wool ewes delivered 10% less lambs per ewe joined than the controls of that strain due to small but cumulative deficits in conception rate and fecundity. Differences in lambs born per ewe joined between selected and control ewes of the other strains were smaller (range 2-4%). Where deficits in lambs born occurred, these were compounded by moderately lower lamb survival in the 3% and 8% MP medium wool lines and in the selected broad wool line. This was also evident in the selected fine wool line which suffered a significant 12% reduction in lamb survival compared to the fine wool control ewes. The net result was significant deficits in weaning percentage of 14% in each of the fine and broad wool selected lines and 9% in the 8% MP medium wool line. Although not significant, the 3% MP line also weaned 5% fewer lambs per ewe joined than the medium wool controls. In contrast neither the Industry nor the 15% MP line showed any decline in any of the components of reproduction relative to the medium wool control line ewes.

The genetic correlations between weaning percentage (for example) and the traits under selection suggest that some decline in reproduction should be expected and would result more from selection for increased clean fleece weight than for finer fibre diameter. Although for both traits the genetic correlations with weaning percentage are unfavourable, the genetic antagonism is stronger with fleece weight (rg -0.26) than for fibre diameter (rg 0.06). To place these observations in perspective, we would expect reductions of around 9% lambs weaned per ewe joined after 10 years of single trait selection for clean fleece weight of the intensity applied in the PLU$ lines. Additional selection for fibre diameter might be expected to increase the rate of decline in weaning percentage. Because we have already observed larger reductions in weaning percentage in the fine and broad wool selected lines from ewes born between five and eight years from the start of selection it is unlikely that these deficits in reproduction are solely of genetic origin. The drops of ewes that our estimates are based on lambed between 2002 and 2006. These were extremely challenging seasons for breeding ewes at Trangie. Although all lines were exposed to the same nutritional regime it is possible that ewes from the high fleece weight lines encountered greater nutritional challenge during late pregnancy and lactation than the less productive 15%

MP and control line ewes. If this was the case it does not explain the Industry line's advantage in terms of weaning percentage. Breeding ewes from this line produced as much wool as the 3% and 8% MP lines (Table 1) yet weaned 7% and 11% more lambs respectively (Table 5). Although the Industry ewes (and rams) were selected on physical conformation together with breeding values for fleece weight and fibre diameter, no direct selection for reproduction was ever imposed in this or any of the PLU$ selection lines. We look forward to more favourable conditions for lambing in the next two years to determine if the differences between the lines observed under drought conditions persist when pasture availability is not limiting production.

Conclusions

The results have clearly demonstrated that in the selection lines responses were achieved in the desired direction.

The selection imposed within the QPLU$ lines can be summarised:

- improvements were observed in fleece weight (0.2-1.0kgs) and fibre diameter (-0.3- -3.1microns). Similar relative improvements were evident in hogget and breeding ewes in each line.

- These were accompanied by increases in body weight, staple strength and yield in most selected lines. Hogget and adult body weight increased in the 3%MP, 8%MP and 15%MP medium wool lines. Staple strength increased in the 8%MP fine wool line (hogget and adult) and in the 3% and 8% medium wool lines. Yield increased in the fine and broad 8% lines (hoggets and adult) and in the adults of the medium 3%MP and 8%MP lines

- Standard deviation of fibre diameter (SDFD) was reduced in the adults of 8%MP, 15%MP and Industry medium wool lines and in the selected broad wool line (hogget and adult). Coefficient of variation of fibre diameter (CVFD) increased in the adults of the selected fine wool line.

- Among the style traits dust penetration was reduced in the fine and medium wool 8% MP lines (hogget and adults), crimp improved in all selected medium wool lines and staple definition improved in the Industry line, 8%MP and 15%MP.

- Classer grade improved in the Industry line, 3%MP and the 8%MP selected group for fine and broad wool.

- Under drought conditions there were small differences in fertility and fecundity but significant decline in lamb survival and weaning percentage in the fine 8%MP line, medium wool 8%MP line and the broad wool 8%MP line. Breeders need to consider reproductive performance when crafting selection indices.

Which QPLU$ breeding objectives produced the greatest wool income during the period of selection and the highest gross margins in the later drops?

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Introduction

Choosing the correct wool breeding objective is a critical decision in the business of breeding Merinos. Because fleece weight and fibre diameter account for around 90% of the value of fleeces, the selection emphasis applied to each of these traits needs to be carefully considered. Although other wool quality and production traits can be included in the breeding objective to optimise wool prices and contain production costs, the most important decision for wool breeders is to determine the appropriate selection for fleece weight relative to fibre diameter. Within the 10 year life of a breeding objective the decision should be based on a breeder's forecast of price premiums for wool 1-2µm finer than their current flock average. History shows that the premiums for finer wool are volatile (Figure 1) particularly below 22 µm and supply relative to demand is difficult to predict.

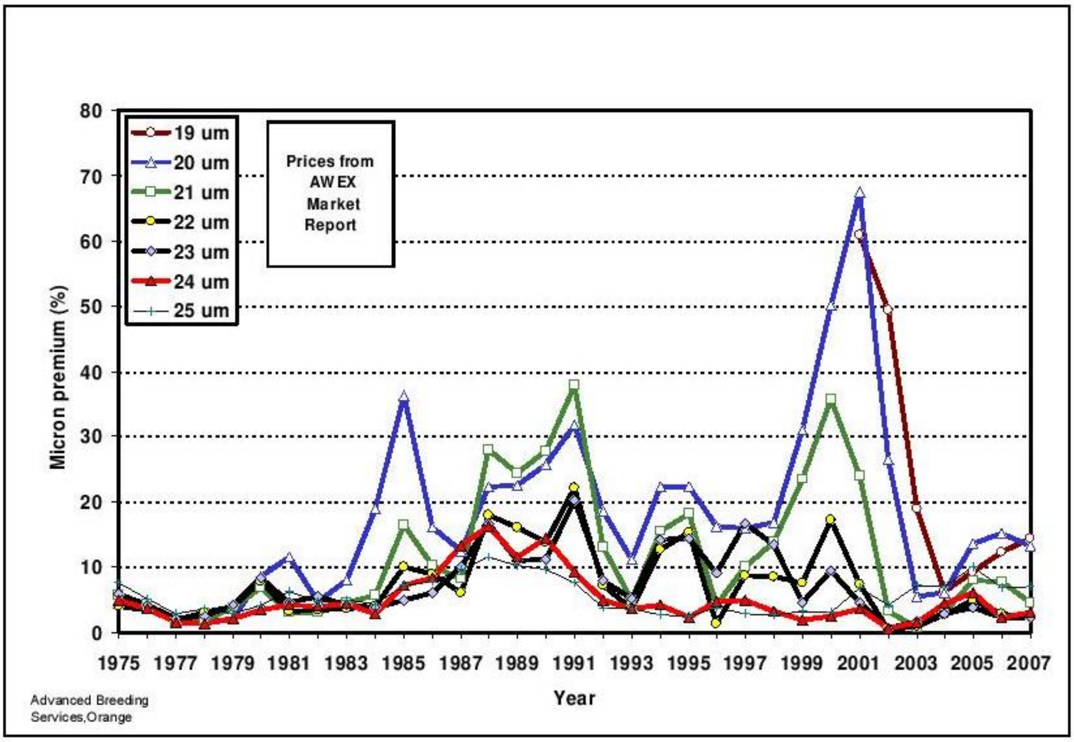

Figure 1 Micron Premiums* for 19 to 25 micron indicators - 1975 to 2007
*(*the percentage increase in price per kilogram for a reduction of one micron)*

From the inception of the QPLU$ Project, the design included selection lines within the medium wool strain driven by selection indexes that placed more or less pressure on fleece weight relative to fibre diameter. They ranged from a breeding objective to

maximise fleece weight while maintaining fibre diameter to a breeding objective to minimise fibre diameter while maintaining fleece weight. The intermediate line's breeding objective was to achieve equivalent improvements in both traits. These were considered to be representative of the range of wool breeding objectives likely to be in place or to be implemented within stud and commercial Merino flocks. The lines were created to demonstrate the improvements in the traits under selection and identify changes in other wool quality and production traits as reported in the preceding paper. The lines have also provided a unique set of data to retrospectively evaluate the wool revenue derived from each breeding objective during the period of selection.
Although there are still two years of production data to collect from the last two drops of breeding ewes, we have completed an evaluation of the selection lines up to and including the 2003 drop breeding ewes. We have also used the estimates presented in the preceding paper together with the carcass means presented in these proceedings last year to calculate hogget and adult gross margins based on mutton and wool for ewes born in the later years of selection.

Improvements in the value of adult fleeces of each line during the period of selection

Because of their large contribution to the wool production of self replacing Merino flocks we based this analysis on the fleeces produced by the breeding ewes of each selection line. For each ewe we calculated an average lifetime clean fleece weight and mean fibre diameter based on the wool produced from two to five years of age. Fleece weights and fibre diameters were adjusted for the non-genetic effects of the number of lambs born and reared each year, the ewe's age when shorn and the year in which the fleece was grown. From these estimates we calculated mean lifetime fleece values for each drop of breeding ewes born in each selection line between 1995 and 2003. The three fleece values were based on wool prices prevailing between 1995 and 2006. These included a low micron premium scenario (2004 – 2006), a high micron premium scenario (2000 – 2002) and the actual prices prevailing in the year that each fleece was shorn (1997 – 2005). Fibre diameter price curves for each market scenario are depicted in Figures 2 and 3.

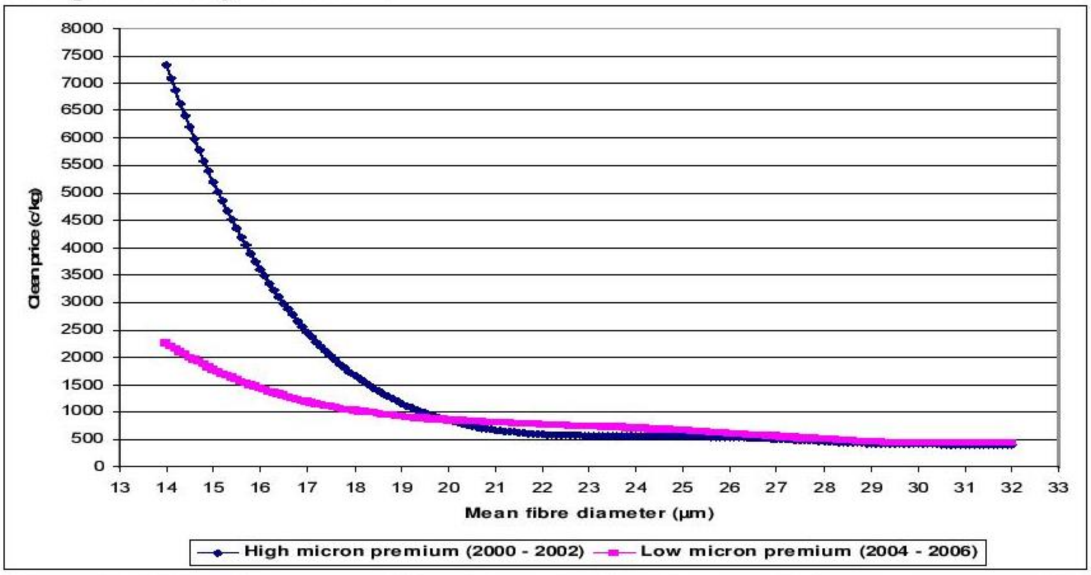

Figure 2 Prices for mean fibre diameter for high and low micron premium scenarios

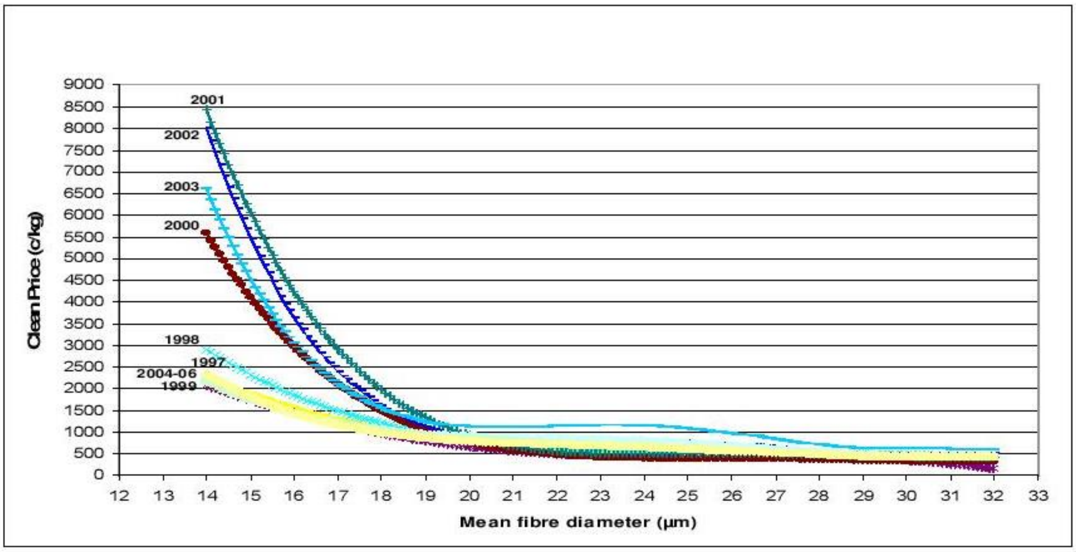

Figure 3 Prices for mean fibre diameter – 1997 to 2006

Results and discussion

The deviations in fleece value of each medium wool selection line from the medium wool control line are shown in Figures 4, 5 and 6 for the low micron premium, high micron premium and actual micron premium market scenarios respectively.

Regardless of market scenario and breeding objective, all medium wool selected lines have increased in fleece value relative to the control line.

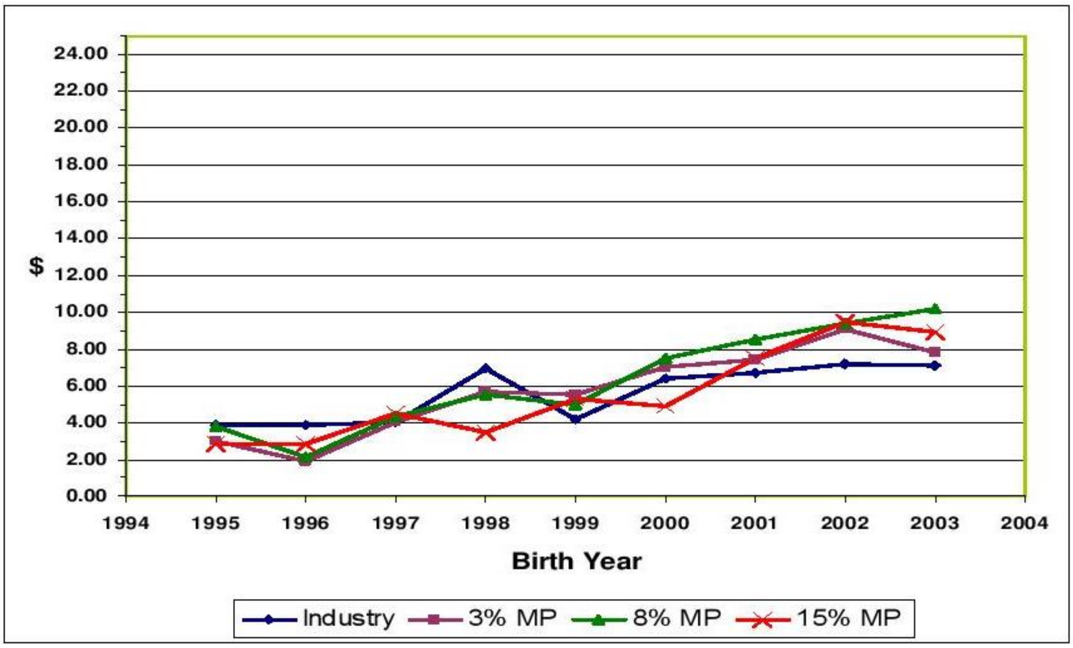

Figure 4 Increases in fleece value above controls in the low micron premium market

Under the low micron premium market (Figure 4) there was relatively little variation among the lines in fleece value (less than $4.00 in any drop) which was driven more by responses in fleece weight than fibre diameter. Under this market, the fleece value premiums peaked at between $7 and $10 dollars per fleece in the 2003 drop. Across the eight drops, the Industry, 3%, 8% and 15% lines averaged fleece value increases above the controls of $5.58, $5.71, $6.26 and $5.53 respectively.

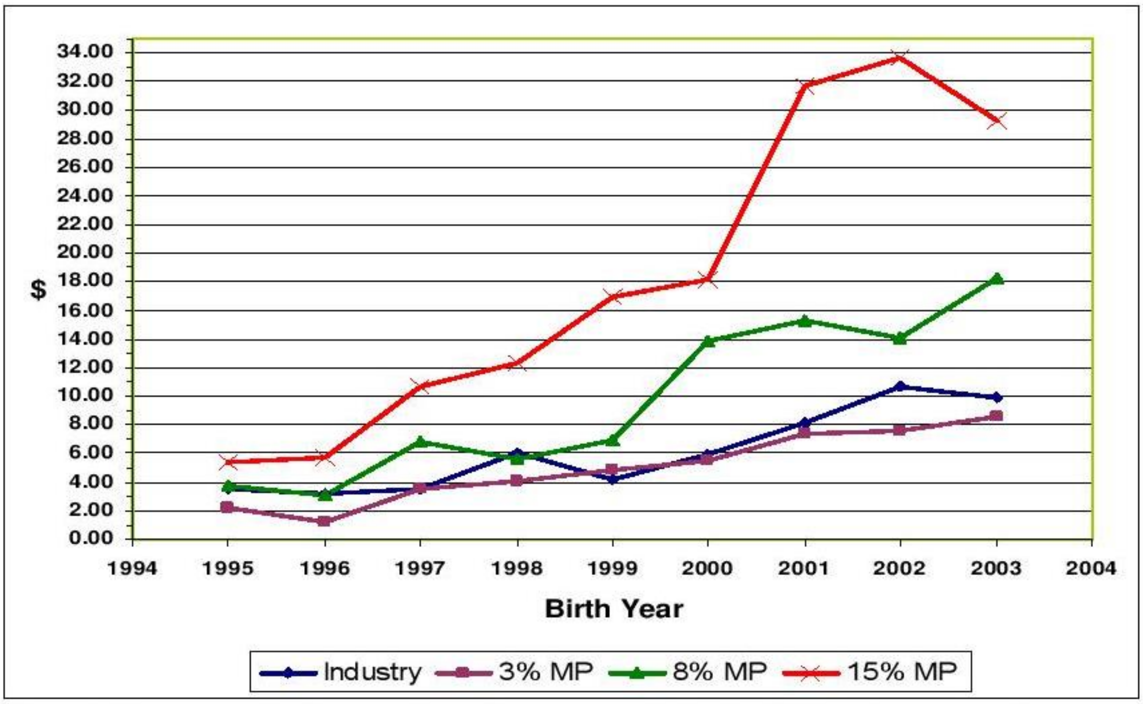

Figure 5 Increases in fleece value above controls in the high micron premium market

In contrast, under the high micron premium scenario (Figure 5) the fleece value responses diverged markedly between lines, driven by responses in both fleece weight and fibre diameter. Under this scenario the increases in fleece value peaked at between $8.50 and $34 per fleece. Between 1995 and 2003 drops, the average premiums for the Industry, 3%, 8% and 15% lines were $6.13, $4.99, $9.75 and $18.21 respectively.

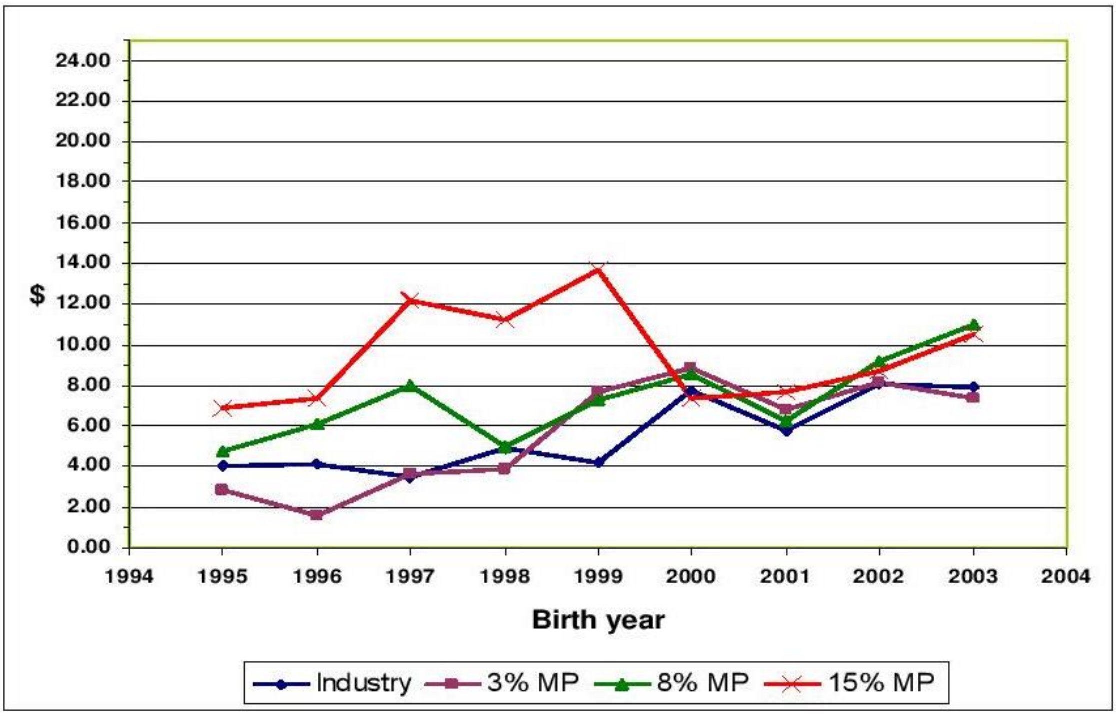

Figure 6 Increases in fleece value above controls in the actual market

Under the actual market conditions prevailing in the year that each fleece was shorn, across the eight drops, the Industry, 3%, 8% and 15% lines averaged fleece value increases of $5.58, $5.65, $7.35 and $9.51 respectively. From Figure 6 it is evident that the increased average premiums of the 8% and 15% over the 3% and Industry lines accrued from the fleeces shorn during years of relatively high micron premiums. This was particularly evident for the first five drops of the 15% line which produced the majority of adult fleeces during the period of relatively high micron premiums from 1998 to 2002 (Figure 1). Interestingly the 1999 drop of the 15% line recorded the highest average fleece value for the period even though that drop produced only two adult fleeces during the period of high premiums (2001 and 2002). Those two fleeces were the finest adult fleeces produced by the drop (at two and three years of age) that coincided with two years of very high micron premiums.

Although the underlying genetic improvement in fleece value observed in all lines in all three market scenarios is obvious, the majority of the additional wool income from the 15% line accrued in three drops (1997 – 1999) in the first half of the breeding program. As indicated by Figure 5, the average fleece value advantage of the 15% line over all other lines would have greatly increased had high micron premium market conditions coincided with the fleeces produced by the finer, later drops bred within that selection line.

To evaluate the economic trade-offs in choosing a wool breeding objective in an uncertain market for fibre diameter, we need to compare the average returns from each breeding objective under each market scenario. Table 1 compares the average fleece value across all eight drops of the three purely measured lines (3%, 8% and 15% micron premium lines).

Table 1: Fleece value deviations of the 3% and 15% MP lines from the 8% MP line

Selection Line	Low MP market	High MP market	Actual MP market
3% MP	- $ 0.55	- $ 4.76	- $ 1.70
8% MP	$ 41.89	$ 37.43	$ 40.85
15% MP	- $ 0.73	+ $ 8.46	+ $ 2.16

Under all market scenarios the 3% MP line (high fleece weight, maintain diameter) produced fleeces of lower value than the 8% MP line. The deficit was small (1.3%) during the low micron premium market but substantial (12.7%) under the high micron premium market. In contrast, although the 15% MP line (reduce fibre diameter, maintain fleece weight) also produced fleece values marginally below (1.7%) the 8% MP line in the low micron premium market, it greatly compensated (+22.6%) under the high micron premium scenario. Under the volatile micron premium conditions experienced during the period of selection, the net average fleece value favoured the 15% line by 5.3% above the 8% MP line and 9.9% above that of the 3% MP line.

Genetic analysis of the variation in individual animal fleece value provides some further explanation of the genetic response in fleece value observed within the QPLU$ lines. Fleece values for ewes at the high MP, low MP and actual market value were analysed with a genetic model that estimated the variances due to genetic, permanent environment and error sources, together with covariances estimated from bivariate analyses. The results are presented in Table 2.

Table 2: Genetic parameters for fleece value

	High MP	Low MP	Actual market
Phenotypic standard dev.	$11.53	$5.78	$8.37
Heritability	0.48	0.37	0.26
Repeatability	0.72	0.71	0.54
Correlations†			
High MP	-	0.65	0.93
Low MP	0.67	-	0.82
Actual market	0.64	0.65	-

† Genetic correlations above the diagonal, phenotypic correlations below

Heritability and repeatability

In the high MP market, fleece value is determined by both fibre diameter and fleece weight. The genetic parameters of high MP fleece value reflects this with a heritability of 0.48 and a repeatability of 0.72, values that are intermediate between the respective values for fibre diameter and fleece weight. In the low MP market, fleece value is largely determined by fleece weight, and the heritability of 0.37 and repeatability of 0.71 are very similar to the expected parameters for fleece weight. In the actual market scenario, the error component is inflated because of between-year price variation. This causes a severe reduction in both heritability and repeatability which means that an animal's ranking in one year will often be very different in the next year even though its fleece weight and fibre diameter may be similar.

Phenotypic variation

The variation between ewes was greatest in the high MP market, lowest is the low MP market and intermediate in the actual market. The importance of phenotypic variance is that it determines the selection differential possible under any given selection intensity and in conjunction with the heritability determines the rate of genetic improvement.

Correlations

Fleece values under the three market scenarios were highly correlated at the phenotypic and genetic levels. The genetic correlations between the high MP and actual markets were very high, reflecting that periods of high MP have a large influence on overall response whereas periods of low MP, with its lower variation, are less important to overall economic response.

Expected responses to selection

Based on the contents in Table 2 we have calculated the expected increases in fleece value per generation in each of the three markets (Table 3).

Table 3 Expected responses to selection per generation under each market scenario

	Expected response in each market		
Market selected for	High MP	Low MP	Actual market
High MP market	$5.53	$1.58	$2.75
Low MP market	$3.16	$2.14	$2.13
Actual market	$3.79	$1.47	$2.18

Selecting for a high MP market (principally for fibre diameter) will lead to substantially greater increases in fleece value in the high MP market. Similarly, selecting for a low MP market (principally for fleece weight) will lead to marginally greater response in the low MP market. But for the actual market, a high MP selection regime yielded greater response than using either the low MP or actual market. If selecting to maximise response in a variable market, the cumulative responses in fleece value will be highly influenced by the degree of response in periods of high MP. Attempting to maximise response in periods of low MP will be of limited value unless the market remains fixed at a very low level. Equally, selecting on the basis of current value leads to lower response because of lower heritability and repeatability. Responses observed in the selection lines demonstrate this pattern. For example, the 15%MP selection line (equivalent to selecting for a high MP market scenario) gave the greatest response in both the high MP and actual market scenarios and was competitive with the other lines even in the low MP market.

Gross margins analysis of the 2004 drop hoggets and the 2000–2003 drop adult ewes

Having established which of the medium wool breeding objectives delivered the highest average fleece value during selection, we now consider the gross margins (income minus variable costs) for the 2004 drop hogget and 2000–2003 drop breeding ewes. Within each age group, selection line averages for wool value are based on clean fleece weight and mean fibre diameter with premiums and discounts applied according to the differences between the selection lines in all relevant wool traits presented in the preceding paper. Wool prices were calculated using *Woolcheque* based on the past 12 month market averages. Wool values per head account for the proportion and prices of total wool weight sold in lines of fleece, pieces, bellies and locks. Carcass values are based on selection line averages for ewe live weight, dressing percentages and fat scores based on the ram carcass data presented in the 2006 issue of these proceedings. Carcass prices provided by Meat and Livestock Australia are based on over the hooks quotes averaged over the past three years. Skin prices are based on recent quotes in The Land Newspaper for a 24 kg carcass. Variable costs per head of $24.84 per annum are assumed across both age groups based on NSW Department of Primary Industries estimates for 19-23 micron breeding ewes. This cost assumes no supplementary feeding. For breeding ewes, lambs weaned are valued at $20 per head. Gross margins are presented on a dry sheep equivalent (dse) basis by adjusting gross margins per head to a common body weight of 45 kg across all lines. Income per head and lifetime gross margins in the current market are presented in Table 5. Wool values are presented as per head and per dry sheep equivalents for comparative purposes.

Table 5 Income per head and gross margins per 45 kg dry sheep equivalent – 2006-07

Strain		Fine wool		Medium wool					Broad wool	
		8%	C	Ind.	3%	8%	15%	C	8%	C
Wool ($) / head	h	35.74	27.30	42.35	43.40	46.14	45.84	35.41	40.94	30.48
	a	36.86	26.06	40.80	40.22	41.43	42.08	33.74	42.50	28.97
Wool ($) / dse	h	33.72	26.51	37.48	39.10	40.84	42.05	32.78	33.83	24.58
	a	31.50	22.27	32.13	31.92	33.41	34.21	28.11	31.25	21.46
Lamb /year ($)		14.00	16.80	20.40	19.00	18.20	20.80	20.00	16.40	19.20
Adult carcass ($)		42.62	43.86	48.98	47.94	47.72	46.60	45.44	52.31	53.47
Adult skin ($)		8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00
GM /head/year ($)		33.12	25.28	43.99	42.41	43.24	45.55	35.92	42.53	32.09
GM /dse/year ($)		28.31	21.61	34.64	33.66	34.87	37.03	29.93	31.27	23.77

In the current wool market, a period of relatively low premiums for fine wool, differences in wool income between the selected and control lines are consistent with the observations made earlier in this paper. Among the selected medium wool lines hogget and adult wool values fall within the ranges of $3.50 and $1.86 per head respectively. All selected lines are at least $6.94 and $6.48 above the hogget and adult controls respectively. Margins between the selected and control lines of the fine and broad wool strains are larger at $8.44 and $10.46 for hoggets and $10.80 and $13.53 for breeding ewes respectively. Similar margins between selected and control lines are evident when corrected for differences in body weight as indicated by wool values per DSE for each age group. To correspond with the purpose of breeding ewes, we have calculated the average annual gross margin based on whole of life production for each selection line. This assumes that the ewes are sold over the hooks eight weeks off-shears at five years of age having produced a hogget fleece, four adult fleeces and had four opportunities to lamb. Annual gross margins of the selected medium wool lines fall within $3.37 per DSE. Compared to the control line ewes, the selected lines earned between $7.10 (15% MP) and $3.73 (3%MP) more per DSE per year. Differences between the selected and control lines of the fine and broad wool strains are similar at $6.70 and $7.50 respectively.

Although these are worthwhile improvements in profit across all strains they represent estimates of response close to the bottom of the range expected. While premiums for fibre diameter have been lower (eg 2004, Figure1), current micron premiums for 21µm and finer wool are well below the average for the past 20 years and are approximately 55% of the premiums in the market since 1996 for the 21 -19 micron indicators. The other confounding concern is that the gross margins are based on production and wool quality differences between the selection and control lines measured under drought conditions. This not only has the potential to reduce production in the selected line relative to the controls, but impacts on the style and staple strength of the wool which has imposed disproportionate discounts on the price per kilogram of the finer lines. Although the ewes have obviously been well managed during the measurement period (see body weights in preceding paper), we are at this stage unsure of the potential of these later drops to produce wool and lambs under what used to be the normal cycle at Trangie of winter annual pasture – summer lucerne/crop stubble. At this stage the production of the 2003 and 2004 drop ewes will be monitored until the end of 2008.

Conclusions

In terms of setting strategic breeding objectives, the results of this analysis indicate that Merino breeders should:

- Choose a likely micron premium scenario within realistic ranges and position the objective towards the upper end of that expectation
- Commit to the breeding objective for a minimum of 5 years
- Maximise returns in periods of high micron premiums and survive the downturns to maximise overall profit

QPLU$ messages for ram breeders

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Messages in brief

- A ram breeding flock's future genetic progress can be accurately and easily predicted.
- Merino ram breeders' flocks based on a wide range of bloodlines and wool types can make a high rate of genetic progress for any one of a wide range of breeding objectives of their choosing.
- The genetic progress that is made by a ram breeding flock can be accurately and easily described.
- Breeding values can accurately describe the genetic performance of sheep for a wide range of measured and visually assessed traits. Breeding values are a more accurate evaluation of the genetic performance of a trait than measured performance alone.
- A selection index accurately describes a sheep performance for a combination of traits that match a stud's breeding objective for these traits.
- Breeding values and a stud's index can be accurately and effectively used to select the rams and ewes that will maximise genetic progress for these traits in a ram breeding flock.
- A stud breeder can visually assess sheep for a wide range of wool quality and soundness traits and use this in combination with the sheep's breeding values and index value to make accurate selections relative to their breeding objective.
- Carcass characteristics were largely not affected by selection for fleece weight and fibre diameter with the exception of a negative effect on loin pH.
- Selecting for fleece weight and fibre diameter is likely to improve the efficiency of turning pasture into wool.

The following sections provide more detail on the above brief messages. At the conclusions of the paper I have provided recommendations relating to the messages.

The objective of the QPLU$ project

The QPLU$ project was established to allow Merino stud breeders to confidently and successfully use breeding and marketing strategies that utilise EBVs (Estimated Breeding Values) and selection indexes. To achieve this objective the QPLU$ sheep flock was established (Akins and Taylor 1998).

Stud quality sheep from fine, medium and broad wool bloodlines were purchased to form the QPLU$ stud. Five selection lines were established within the stud. These lines were selected solely on fleece weight and fibre diameter (Table 1). In addition a sheep classer selected (Industry) line was also established. To allow each line's genetic progress to be defined, each of the three bloodlines involved maintained a randomly bred (Control) line. All lines were bred for 10 years and their genetic progress calculated.

Table 1. QPLU$ Selection lines

Wool type - bloodline	QPLU$ selection line
Fine Wool – Merryville	- 8% Micron Premium - Control (random selected)
Medium Wool – Haddon Rig	- 3% Micron Premium - 8 % Micron Premium - 15% Micron Premium - Industry (Classer selected) - Control (random selected)
Broad Wool – East Bungaree	- 8% Micron Premium - Control (random selected)

Breeding and marketing messages

Past and the present QPLU$ Open days have revealed many valuable messages for Merino ram breeders and commercial breeders. Most of these messages are based on QPLU$ research outcomes.

The QPLU$ messages can assist ram breeders to further develop or confidently maintain their stud's breeding and marketing system knowing that it is highly effective.

While it is obvious that a ram breeder's business relies heavily on the breeding system they use, the great majority of ram breeders must also be successful marketers. Marketing is not only important to the ram breeder's business but also to the commercial flocks that rely on a ram breeder to supply their rams. Commercial flock breeders must be able to identify the studs and the rams that will allow them to maximise the genetic progress of their flocks relative to their flocks' breeding objectives and their budgets.

The following points summarise the main messages for ram breeders that have resulted from the QPLU$ research. Even though the 10 years of selection planned for the project has been completed, QPLU$ research is continuing and therefore additional messages will be reported in the future.

1. Genetic progress can be accurately and easily predicted.

The fact that the genetic progress achieved by each of the QPLU$ selection lines was similar to the progress predicted before selection began is a clear demonstration that within-flock genetic progress can be accurately predicted.

Figure 1 uses a dotted line to describe the predicted genetic progress for each of the Medium Wool index selection lines fleece weight and fibre diameter. The associated solid line describes the progress achieved by each of these lines. The progress made by the Industry (Classer selected) line is also described. Figures 2 and 3 describe the Fine and Broad Wool selection lines predicted and achieved progress.

Since the start of the QPLU$ project, the procedures and information used to make predictions of genetic gains in ram breeding flocks have improved. Therefore current and future predictions that are made for ram breeders will be even more accurate than those made for QPLU$ over ten years ago.

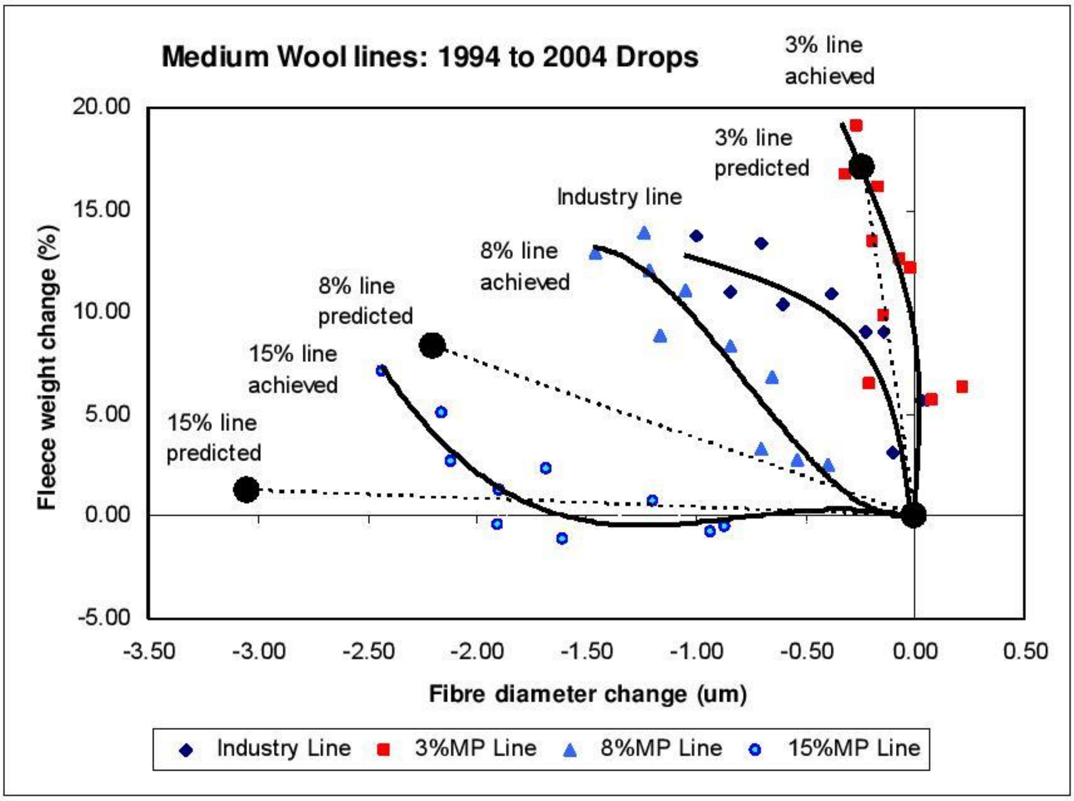
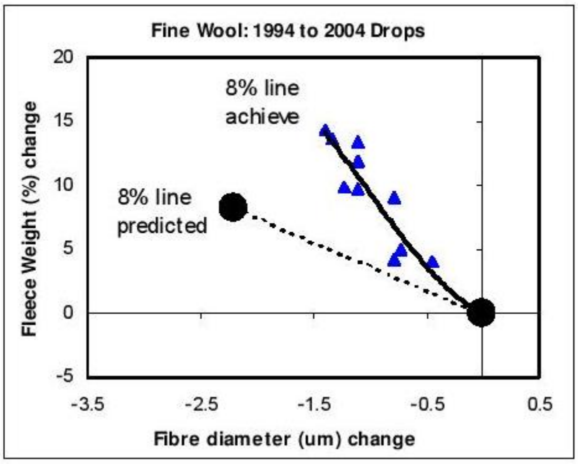


Figure 1. Medium Wool: 3%, 8% and 15% lines (predicted and achieved genetic progress) and Industry (Classer selected) line (achieved genetic progress)



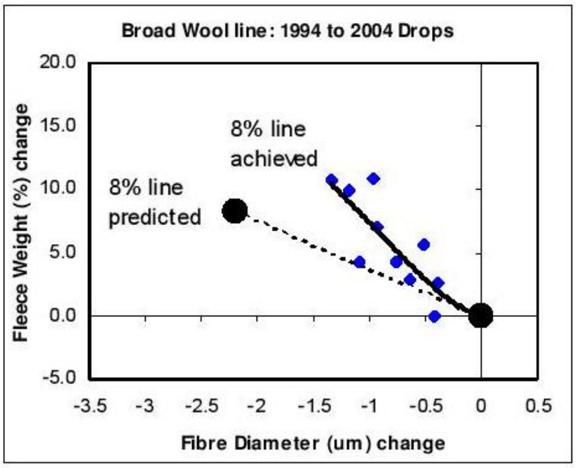


Figure 2. Fine Wool: 8% line (predicted and achieved genetic progress)

Figure 3. Broad Wool: 8% line (predicted and achieved genetic progress)

The process of predicting genetic progress is available as a service to ram breeders. This process allows a breeder to consider variations to a current breeding program. The genetic progress achieved by various breeding strategies can be described, thus allowing breeding advantages to be considered relative to any additional costs and effort required.

The end result of this process is a clearly defined "breeding objective". This breeding objective will not be based on hope but instead be based on a clear understanding of what can be achieved and the resources required.

The breeding objective is a critical component of planning and therefore is central to an effective breeding program. In addition the breeding objective is an important component of a modern marketing program. Commercial breeders clearly and understandably feel it is very important to know the standard of performance of the rams they will purchase in the coming years.

It is absolutely critical that the breeding objective is monitored each year. Firstly, the breeding values and index of the selected rams and ewes to be mated should be assessed to see if they are in line with the objective. Secondly, genetic progress that is achieved must be tracked. In combination the two techniques ensure any unexpected outcomes can be quickly adjusted for to ensure the breeding objective is achieved.

2. High rates of genetic progress can be achieved.

High rates of genetic progress were achieved by all the QPLU$ selection lines. Figures 1, 2 and 3 show the progress made by each of the six selection lines from their starting point.

Compared to an industry ram breeding flock the genetic progress of the QPLU$ selection lines were restricted by the research design, including, (i) the small size of each line (200 ewes per line), (ii) having to use a high rate of sires to limit inbreeding as a result of the small size of each line, (iii) not being able to use artificial insemination or embryo transfer to maximise the use of high performing rams and ewes, and (iv) not being able to use outside sires.

QPLU$ selection lines except for the Industry line were only selected for fleece weight and fibre diameter. This narrow breeding objective is not used by industry stud flocks and is certainly not recommended. It is common for other measured traits to be included in a stud's breeding objective. Visually assessed wool quality, structural soundness and type traits should be included in all stud breeding objectives to some degree, depending on the flock's standard for these traits and their importance to the ram breeder's clients.

My experience with studs that have high performance for wool quality, soundness and type traits clearly demonstrates to me that these traits can be selected for with only a 20% to 25% reduction in genetic progress for the measured traits in their objective.

It is therefore very possible that 75% to 80% of the QPLU$ gain can be achieved by industry stud flocks without compromising genetic progress for other traits.

3.Selection for fleece weight and fibre diameter is not in general antagonistic to selection for other wool quality and structural soundness traits.

Selection for fleece weight and fibre diameter did not in general adversely affect wool quality traits or Classers Grade. In fact several wool quality traits including dust penetration, crimp definition and staple definition improved in some selected lines even though the only direct selection was for fleece weight and fibre diameter.

The only wool quality trait to significantly deteriorate was greasy wool colour in the Fine Wool 8% selection line. Inclusion of this trait in the breeding objective would have prevented this deterioration with only a very small reduction in the response in fleece weight and fibre diameter.

The Classers Grade score that includes evaluation of wool quality and structural soundness (without the assistance of measured performance) was generally improved although not significantly in the selected lines, including the Industry line. The exception was the 15% Medium Wool line that was penalised by the classers for shorter staple lengths; however the small negative effect was not significant.

When selecting sheep in a ram breeding flock I would recommend careful evaluation of all sheep for all the wool quality and soundness traits in the flock's breeding objective. However, it is very valuable to know that when selecting for fleece weight and fibre diameter, there is not likely to be a negative flow on effect to wool quality and soundness traits.

The mainly neutral relationships between the measured and visually assessed traits explain why the inclusion of wool quality and soundness traits in a stud's breeding objective only has a small negative impact on the genetic progress for measured traits.

Good genetic progress for production traits is not normally held back significantly by selection for visually assessed traits. Rather the major impediment is the ram breeder's lack of confidence in, and use of, measured trait breeding values to assist them to achieve their breeding objective.

4. Selection for measured and visually assessed traits can be efficiently achieved in practice in a stud flock.

The QPLU$ Industry (classer selected) line was bred using a combination of measured and visual assessment. The rate of genetic progress in the Industry line for fleece weight and fibre diameter was close to the rate of progress made by the Medium Wool 3% selection line (Figure 1).

The Industry line and the Medium 3% line are also similar in performance for wool quality traits and Classers Grade.

I would recommend that even when the industry has breeding values for visually scored traits effective selection will still require a skilled person to make the final stud selection and sale grade selections.

The challenge for breeders is to understand the advantages and disadvantages of relatively new technology, such as breeding values and an index, and use them where appropriate to improve the ease and accuracy of making selections.

It should be remembered that not all ram breeding flocks are as effective as the QPLU$ Industry line at obtaining and using visual and measured trait performance to make selections. This level of gain cannot be taken for granted and all commercial flocks should obtain a Genetic Trend report annually from their ram source that clearly shows the progress being made.

5. Breeding Values can accurately describe the genetic performance of sheep for measured and visually assessed traits.

Breeding values, commonly called EBVs (Estimated Breeding Values) very effectively describe the genetic performance of sheep for fleece weight and fibre diameter. Breeding values for these traits were the basis for the high rates of genetic progress made by the QPLU$ selection lines.

The accuracy of breeding values in describing a sheep's true genetic performance is variable depending on the type of information used to calculate the breeding value. At worst it is as good as the measured performance it was based on. However, its accuracy can be improved 100% - that is, genetic progress can be doubled, if a second evaluation is obtained at a later age and pedigree and birth records are used to calculate the breeding values.

Figure 4 (Russell et al 2006) shows: (A) the genetic gain achieved by QPLU$ Medium Wool 8% line; (B) the improvement that can be expected to be made by a Merino stud that has an 8% breeding objective with 75% of their emphasis on measured traits and 25% on visually assessed traits, utilising full pedigree and 2nd stage selection for rams and ewes, and (C) the same objective and emphasis as B, however does not use birth, pedigree and 2nd stage records to improve the accuracy of selection.

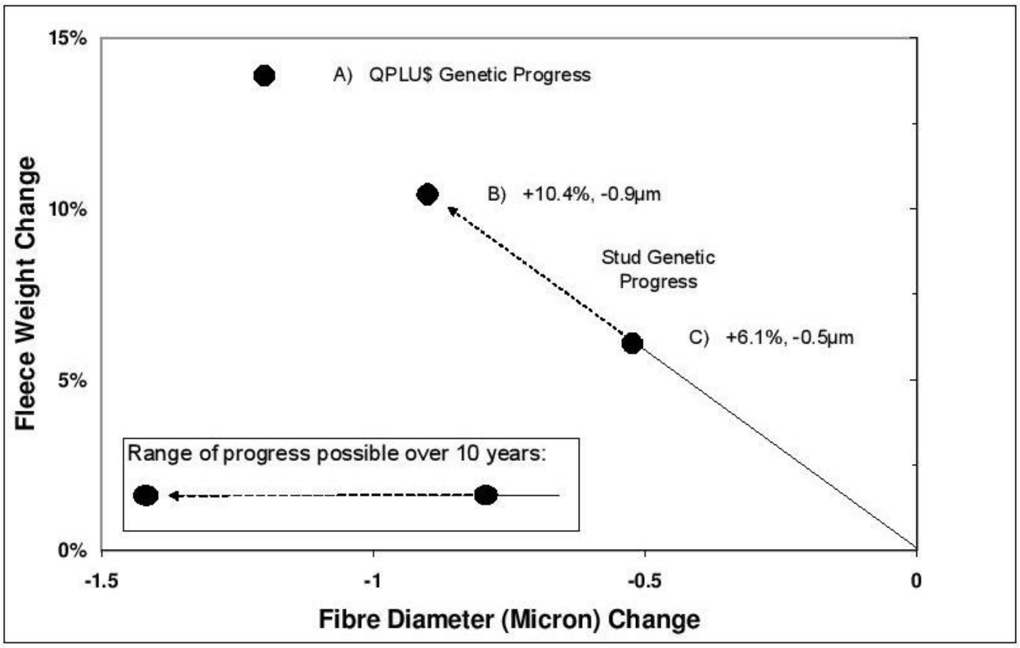


Figure 4. Progress achieved in the QPLU$ project over 10 years and range of progress possible in a Merino stud over the same period.

Pedigree records have another important role over and above improving breeding value accuracy. Pedigree, even a limited amount of sire pedigree, can provide the genetic linkage needed to calculate breeding values that allow the comparison of sheep in different drops – a critical need for all ram breeders at mating.

For many ram breeders, the genetic linkage that can come from pedigree records also allows a direct comparison between sheep in their flock and sheep in other ram breeding flocks.

Accurate selection and use of higher performing rams from other flocks based on across-flock breeding values will further improve genetic progress (in addition to the genetic progress based on use of within-flock breeding values as demonstrated by QPLU$). The use of higher performing rams from other ram breeding flocks to improve genetic progress is not new. However, across-flock breeding values allow the ram breeder to be sure that the outside genetics are significantly better than those available within the stud and thereby increase the success of this strategy.

Breeding values and index values are available from a wide range of service providers including fleece measurement testers, genetic advisors and Sheep Genetics Australia. Sheep Genetics Australia has recently been established to provide across-flock breeding values for each of the meat and wool sheep breeds. The Australian Dohne Association produces across-flock breeding values for that breed. Merino Superior Sires provides breeding values for elite Merino stud sires that they have independently evaluated.

Breeding values can be calculated for a wide range of measured traits, not just fleece weight and fibre diameter. QPLU$ research has contributed significantly to the development of the ability to provide breeding values for visually assessed and scored traits and these will soon be available to ram breeders that have suitable records.

6. Selection indexes are an effective and efficient method to describe a sheep's performance for a breeding objective.

A selection index combines a sheep's breeding values to provide one value that describes the sheep's performance relative to a breeding objective for these traits. QPLU$ selections were based almost solely on an index of fleece weight and fibre diameter relative to the objectives of various selection lines.

The high rate of genetic progress achieved by the selection lines is a clear indication that an index can be an efficient aid to selection. As a summary of performance for several traits, they are an excellent tool to short list sheep for selection. Individual trait breeding values and visual trait performance are essential to finalising selections.

Index values are a valuable marketing tool as they assist ram buyers to accurately and easily select rams for commercial flocks.

It is critical to remember that an index is only as good as, (i) the accuracy of the breeding values used in its calculation, and (ii) how accurately the index reflects the breeding objective of the flock that selections are being made for.

7. Carcass characteristics were not significantly affected by selection for fleece weight and fibre diameter.

Generally the effect of fleece weight and fibre diameter selection on carcase characteristics was small, and in the small number of situations where the difference was significant some were positive and some negative. The most concerning difference was that five of the six selected lines had a significant increase in loin pH.

Other effects were that in the Industry line live weight was improved without a significant improvement in carcase weight. The Industry line and the Medium 8% line had improved eye muscle area. The Broad Wool 8% selection line performed to a lower standard for carcase quantity but was positive for carcase quality.

My recommendation, therefore, is if your breeding objective includes carcass traits, you need to select directly for them. Carcase quantity traits can be easily measured and included in a selection index. Selection for the hard to measure meat quality traits is a concern because of the significant increases in loin pH. Other meat quality traits were either not affected or were positively affected; therefore selection for these traits is not as critical if the breeding objective is to maintain performance.

8. **Selecting for fleece weight and fibre diameter is likely to improve the efficient use of pasture.**

On the basis of the QPLU$ research conducted so far it is reasonable to assume that within bloodlines the selected lines are producing heavier fleeces and finer wool for the same amount of pasture consumed by their bloodline's Control line. If this is the case, the selected lines are more efficient at turning pasture into wool.

Breeding improvement provides real marketing power

As a ram breeder, which group of rams in Figure 5 would you rather be breeding from and marketing? Figure 5 shows the top 20% index rams from the QPLU$ 1994 drop Medium 8% line as a "+" and the top 20% 2004 drop Medium 8% line as a "• ".

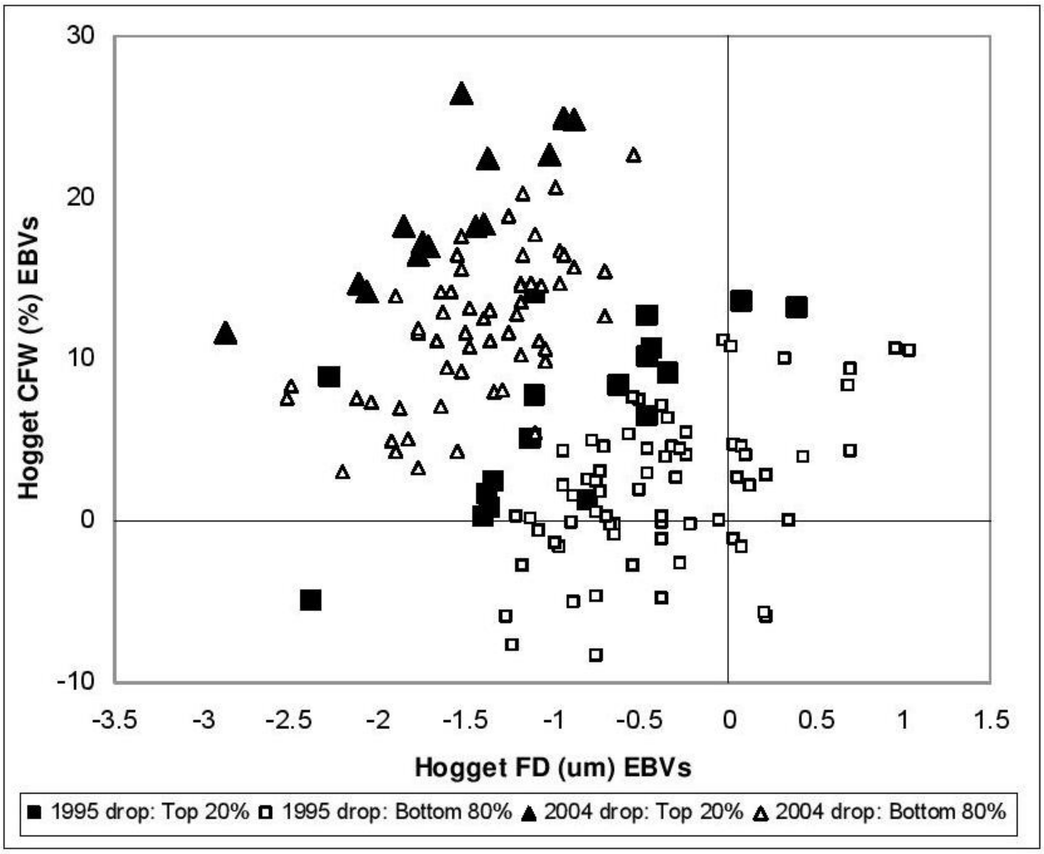


Figure 5: 1994 & 2004 drop Medium 8% rams highlighting the top 20% on index

Clearly the 2004 drop rams in Figure 5 are the much more valuable group of rams to breed from or sell. If implemented correctly, breeding values and an index used as major aids when making selection decisions provide a guaranteed strategy to breed and market rams that are of a much higher standard - and as ram breeders isn't that what you want?

Ram breeders that are not making high rates of genetic progress and/or are not able to demonstrate their flock's progress will be left looking very second rate when compared to breeders making high rates of genetic progress and being able to clearly demonstrate this gain. Production trials (such as wether trials or Central Test Sire

Evaluation) and across-flock breeding value (and the resulting Genetic Trend) are clear ways to demonstrate genetic progress.

At present many rams are sold on the basis of their within-drop measured performance (not breeding values) and prepared to look the part on sale day. The discerning ram buyer is however now more and more requiring breeding values and indexes because they want reliable, easy to use, transparent, profit driven performance information. If they cannot get this type of information, they may well turn to another breed or enterprise that allows them to make sound production decisions. Of course sale rams must be prepared so they can be effectively assessed at the point of sale and are fit to work.

My recommendations

In relation to the messages I have outlined above I would like to recommend that you consider the following if you are a ram breeder:

- Select rams and ewes using breeding values (not raw performance measurements) as they best describe the sheep's genetic performance.
- Use an index that you know accurately reflects your breeding objective to at least give you a starting summary of the performance of sheep being selected.
- Track the genetic progress of each drop of rams and ewes and use it to assist your breeding and marketing.
- Following selection each year, evaluate the group of sheep selected to ensure they are in line with the stud's objective.
- Ensure that where possible you directly select for the traits in your breeding objective – both measured and visually assessed traits.
- When efficient to do so, obtain birth, pedigree and/or 2nd stage performance records and use these to improve the accuracy of the flock's breeding values.
- When efficient to do so, obtain pedigree records (at least some sire pedigree) and use these to provide across-drop and preferably across-flock breeding values, as well as improve the accuracy of the breeding values.
- A suitable person/s should make selections and mate allocations who can accurately evaluate visually assessed traits and then effectively combine the available breeding values and their visual assessment to select the highest value sheep in line with the ram breeding flock's breeding objective.
- Provide ram buyers with breeding values and a range of indexes that are likely to match there breeding objectives.
- Use sires from other flocks if they have a proven capacity based on genetic evaluation to improve the genetic progress of your flock.
- Have an open but pragmatic view to new technology that becomes available and use it if it is effective and efficient in your flock.

All these recommendations are general in nature and they must be considered in relation to the overall breeding program of the flock in question to ensure the best-balanced package. Services are available to assist with all the individual components in the above recommendations, as well as services to assist a breeder develop the most efficient overall program for their needs now and into the future.

Acknowledgments

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QPLU$ messages for commercial woolgrowers

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Messages in brief

This paper discusses three key messages from QPLU$ for commercial wool growers:

- genetic improvement flows from studs to clients
- studs can use genetic information to demonstrate their breeding objectives and genetic progress
- genetic information can be used to help select better flock rams.

The QPLU$ project has demonstrated the use of technology and selection practices that can increase the rate of genetic improvement in ram breeding flocks. The project has shown that very rapid, simultaneous improvements are possible in a number of traits. The benefits to ram breeders are obvious and have been detailed elsewhere in these proceedings. An obvious question seems to be to ask what it all means for commercial wool growers, those buying rather than breeding rams.

Ram buyers may be presented with new, genetic information such as breeding values and index scores. This information may simply be used by the stud to promote its successes. However, this information also puts ram buyers in a much better position to identify rams that will perform as expected when used "at home".

At a more advanced level, commercial wool growers may choose to use some of the technology and selection practices demonstrated in QPLU$, to make better selections (ewes and wethers) within their own commercial flocks. For example, a simple selection index based on fleece weight and/or fibre diameter and/or body weight can be used to rank ewes and wethers to help selections, including allocating them to a wool or meat flock.

Regardless of whether or not ram buyers choose to us use any or none of this information, they can be assured that any increase in the rate of genetic improvement achieved by a stud will be passed on directly to those who buy their rams. Ram buyers do not need to change anything to enjoy *some* of the benefits that will flow from their ram source using the technologies and practices demonstrated in the QPLU$ project.

Genetic improvement flows from studs to clients

If a stud makes a 10% improvement in a trait over a number of years, clients of that stud will find that their flock improves by the same amount over the same number of years. The actual performance of commercial flocks will lag behind that of the stud but the rate of improvement will be the same.

While the rapid responses achieved in the QPLU$ selection lines give an indication of the improvements that studs can make on behalf of their clients, it should be remembered that these improvements were achieved in small, closed flocks. Even more rapid improvement would have been possible in bigger flocks (allowing greater selection pressure) and where outside genetics and artificial breeding practices were able to be used. The achievements of QPLU$ can be surpassed by studs that do not have the same constraints.

Studs can use genetic information to demonstrate their breeding objectives and genetic progress

One of the great benefits to ram breeders of using modern breeding technology is that the information produced makes it much easier for the stud to communicate their goals and progress to clients.

One of the first steps a stud takes in adopting such technology is to set a quantifiable *breeding objective*: what will be improved, by how much and by when. This breeding objective will indicate to clients the improvement they should see in their own commercial flocks.

It is important for commercial woolgrowers to understand the breeding objective of their ram source and decide how well this objective matches their own, as the performance of the commercial flock will closely follow that of the stud flock. The first step for commercial woolgrowers should be to define their own breeding objective so that it can be compared to that of the stud.

The proof that a stud is making the intended progress towards its breeding objective comes in the form of a *genetic trend*. The genetic trend shows the way the breeding values for each trait improve from year to year. Genetic linkage between drops (years) means that the breeding values of different drops can be directly compared, indicating the genetic improvements that have been made, without the influence of changing seasonal conditions. The genetic trend clearly indicates the progress a stud has made and gives clients confidence that the breeding objective will be achieved.

Figures 1 and 2 show the genetic trends for fibre diameter and clean fleece weight **averaged across all QPLU$ selection lines** (including Controls), from the 1996 drop to the 2004 drop. These graphs were produced by Sheep Genetics Australia (SGA). Note that these trend lines do not represent any one selection line and therefore don't match the results from any one QPLU$ selection line. They do however provide an example of the information being presented to ram buyers by studs using genetic information. An example of a genetic trend from an industry flock is included in the paper written by Jock McLaren, also published in these proceedings.

In each case, "0" represents the average performance of Merino sheep in the SGA database in 1990. The "Merino" line represents the genetic trend for all Merino sheep in the SGA database. These graphs provide proof that the genetic merit of sheep born in the QPLU$ flock has been improving and that between 1996 and 2004, the average breeding values have improved from -0.9 to -1.5 microns for fibre diameter and from -3.5% to +3% for clean fleece weight. Note that this improvement is averaged across nine selection lines and three strains of Merino.

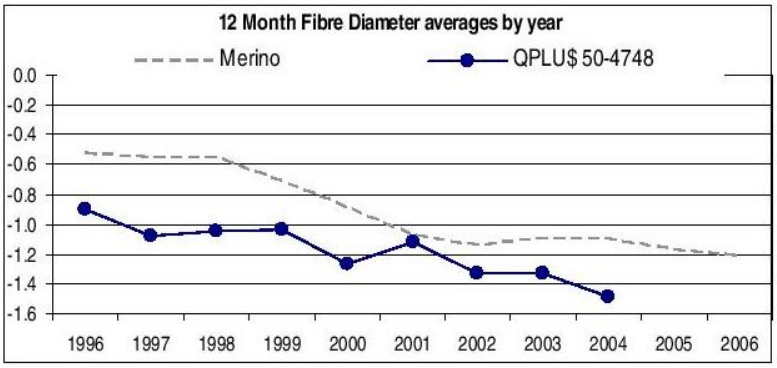

Figure 1: Fibre diameter genetic trend (microns) for all QPLU$ sheep, 1996 drop to 2004 drop, relative to SGA database.

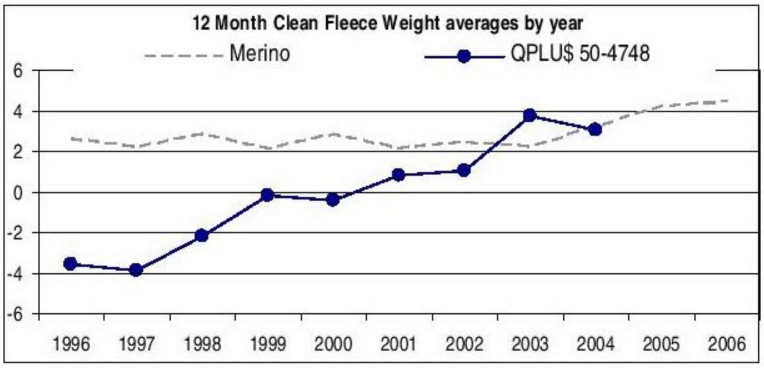

Figure 2: Clean fleece weight genetic trend (%) for all QPLU$ sheep, 1996 drop to 2004 drop, relative to SGA database.

Many studs maintain genetic linkage to the Sheep Genetics Australia database, which means that their breeding values are directly comparable to those of other SGA members. This linkage works in the same way that linkage between drops within one stud works. In these cases the breeding values of individual rams will indicate how they perform relative to the rest of the industry.

Genetic information can be used to help select better flock rams

Some studs provide breeding values and index scores for flock rams. Breeding values give a ram buyer a much better indication of how a ram will perform in his or her own flock. Index scores make the job of weighing up a number of different traits much easier.

Flock rams are purchased for their genes. With respect to production traits, the only reason that a flock ram's own performance is of any interest is because it provides a clue to what the ram's genes might be like – it's breeding value. For example, a heavy cutting ram is likely to have genes for high fleece weight. However, a ram's own performance is not a perfect indication of the performance of its genes. Some sheep will have genes that are better, or worse, that its own performance suggests.

A breeding value gives a much better indication of a ram's genes than does his own performance. This is because the estimate of breeding value takes into account other clues such as:

- additional measurement of the animal itself at an older age;
- measurements of the animal's relatives (pedigree recording); and
- knowledge of the environmental effects into which the animal was born (eg. birth type, rearing type, and age of dam).

Ram buyers will get a much more predictable result when they use a flock ram, if they selected that ram using breeding values rather than its own measurements. Of course ram buyers need to take many traits into account when selecting a flock ram, including traits related to structural soundness. However, to the extent that buyers use measurement to help their decisions, breeding values should be used in preference to the actual measurements.

A selection index is a mathematical equation that calculates an index score. The selection index can include any measured or scored traits and takes into account the relative emphasis that the breeder chooses to place on those traits. That is, it reflects the breeder's breeding objective. The index score combines a ram's performance for a number of traits and ranks it compared to other rams.

A stud can choose to publish index scores for their flock rams calculated by any number of different indexes. One will usually be the stud's own index but others might be published to help ram buyers that prefer to buy rams that are, for example, at the heavier cutting or finer end of the catalogue.

Ram buyers that use several measurements to help choose their flock rams will find that index scores make the job of balancing a ram's performance for a number of traits much easier. The selection index can take care of measured traits, allowing the ram buyer to focus on important visually assessed traits such as structural traits.

Conclusion and recommendations

Ram breeders that use the technologies and selection practices demonstrated by the QPLU$ project can make rapid genetic improvement in several traits. These improvements will be passed on directly to their clients. Ram buyers don't need to change their practices to receive the genetic improvements achieved by their ram source.

Additional benefits can be gained by ram buyers who choose to make use of the genetic information that ram breeders make available to them. These benefits include a more predictable result when flock rams are used and a simpler process for selecting flock rams.

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Balancing selection on measured and visually assessed performances in Merino breeding programs

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The breeding objectives of all ram breeders include visually assessed traits. The visually assessed traits are the platform for production traits (e.g. conformation traits), contribute to economic value of production (e.g. wool quality traits) or influence the cost of production (e.g. fleece rot).

Performance reports for rams currently provide information on production and some disease traits but little if any information on important visually assessed traits. Ram breeders, or buyers, may be very reluctant to use rams that have superior genetics for measured traits but have no information on visually assessed traits. This may restrict them to local flocks, flocks owned by ram breeders well known to the breeder sourcing the genetics, or where the animal itself or its progeny can be inspected.

An important outcome from the Trangie QPLU$ Project is that Merino breeders are being provided with information to help them choose a balance of selection on measured and visually assessed traits that will achieve their breeding objective. Some of this information is evident in the substantial gains achieved by the QPLU$ Industry line towards its breeding objective, under the guidance of John Williams who used selection strategies that combined measured and visually assessed performances. Following ten years of selection, the visual classing used in this line did not compromise responses achieved in fleece weight and fibre diameter (Mortimer et al. 2006). Additional information comes from the QPLU$ index selection lines, where improvements occurred in classer grade, fleece structure and style (staple and crimp definition, dust penetration) after ten years of selection, together with the predicted changes in fleece weight and fibre diameter (Taylor et al. 2006).

Information to assist breeders has also been derived in the form of estimates of heritability for the visually assessed traits and, more importantly, the genetic and phenotypic relationships among the visual traits and measured traits. Although it has been known that visually assessed traits appear to be at least moderately heritable, the accurate estimates of correlations, required for incorporating visually assessed traits into genetic evaluation, have not been available. With funding from AWI (Project EC750), a wider range of genetic parameter estimates for visually assessed traits have been estimated from data of the Trangie QPLU$ project, the CSIRO Fine Wool Project and the South Australian Base Flock and Selection Demonstration Flocks.

The visually assessed traits covered by Project EC750 were classer grade, wool character, fleece colour, handle, fleece rot resistance, neck and body wrinkle, face cover and leg structure (via front legs and back legs traits). Some conclusions to date include:

- Some, but not all, of the visually assessed traits were affected by early environmental effects. Progeny born and raised as singles or of adult ewes had better classer grades, handle and colour scores and higher (i.e. more wrinkly) neck and body wrinkle scores. Older animals at scoring had better classer grades and leg structure scores.

- The project confirmed that most visually assessed traits are moderately (classer grade) to highly heritable (neck and body wrinkle, handle, fleece colour, wool character and face cover), except for fleece rot resistance and the leg structure traits (these traits are lowly heritable).

- In general, selection to improve the score of a visual trait would result in a favourable correlated or negligible response in another visual trait. Most genetic correlations among the visual traits tended to be negligible to low in size and generally positive. Exceptions, in terms of the strength of the relationship, were the genetic correlations between neck and body wrinkle scores (0.93), classer grade and handle (0.46), classer grade and colour (0.52) and handle and colour (0.53).

- Many of the visual traits were phenotypically uncorrelated, with most phenotypic correlations between -0.20 and 0.20. The exceptions were the high positive correlation between neck and body wrinkle scores (0.70) and the low positive correlations of classer grade with each of handle (0.22), colour (0.25), front leg (0.25) and back leg (0.26) and handle with colour (0.29).

- Based on the genetic relationships among the visual traits and the measured traits, single-trait selection for improvements in either of clean fleece weight or body weight will have favourable responses in classer grade but unfavourable responses in fleece rot class. Selection for improved clean fleece weight should result in increases in neck and body wrinkle scores. Genetic improvements in fibre diameter should be accompanied by favourable changes in handle, wool character and colour scores. Selection for higher body weights should result in lower scores for neck and body wrinkle and face cover, with improvements in leg structure scores.

- Project EC750 compared predicted genetic responses in ten years in a typical ram breeding flock to index selection using a range of standard MERINOSELECT indexes that had been modified to examine responses in visual traits under different scenarios. Selection, based on measured performance for complex breeding objectives, is not expected to lead to deterioration in most visual traits. Selection is predicted to result in some improvement in all visual traits, except fleece rot class (across the range of indexes examined) and colour from indexes that emphasised fleece weight. Improvements were largest for handle, wool character and colour for indexes that emphasised fibre diameter. Classer grade showed consistent small improvements across a range of indexes.

- For many production systems, visual and measured traits should be included in selection indices. In some instances, substantial improvements in fleece weight and fibre diameter can be achieved via a mix of visual assessment and measured performance. Handle, wool character, colour and classer grade did contribute markedly to the overall responses in genetic merit of the MERINOSELECT indexes (improvements in accuracy of predicted genetic merit of about 3% (for classer grade and colour) to on average 18% (for handle) on inclusion of each of these traits in the selection criteria). In other instances, inclusion of a visual trait among the selection criteria for the standard MERINOSELECT indexes had only a negligible effect on the predicted responses in the measured traits and the visual traits.

- Visual and measured traits should be included in the index to allow greater genetic progress through more efficient selection strategies. Including visual traits as selection criteria in an index provides the opportunity for greater and more effective use of selection differential for economically important traits, from the removal of the loss of 30% or more of the effective selection differential assumed to be directed to visual traits independent of the measured traits.

- Some visual traits may be considered for inclusion in the breeding objective e.g. fleece rot. This will require evaluations of breeding strategies (e.g. desired gains approaches) that achieve the required improvements in the visual trait together with improvements in other breeding objective traits such as fleece weight and fibre diameter.

Acknowledgement
The contributions of the collaborating organisations to AWI Project EC750, 'Visual Traits in Across-flock Genetic Evaluation', through data provided by Forbes Brien and Richard Grimson (SARDI) and Andrew Swan and Heather Brewer (CSIRO) are acknowledged. The efforts of staff of NSW Department of Primary Industries in support of the QPLU$ project are noted, as well as the work of Amity Chase in support of AWI Project EC750.

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