final report

Project code: B.SGN.0027

Prepared by: Dr Janelle Hocking Edwards

South Australian Research and Development Institute

Date published: December 2007

ISBN: 9781740362849

PUBLISHED BY
Meat & Livestock Australia Limited
Locked Bag 991
NORTH SYDNEY NSW 2059

Influence of Merino genes on prime lamb production

Merino genes in prime lamb production

Meat & Livestock Australia acknowledges the matching funds provided by the Australian Government to support the research and development detailed in this publication.

Abstract

Merino genes play an important role in prime lamb production in Australia with the majority of lambs slaughtered containing some proportion of merino genes. The aim of this project was to determine the effect of Merino genetics in prime lamb production systems, extending the outcomes from the Maternal Central Progeny Test. Merino rams influenced some of the profit drivers of the prime lamb business, including the number of lambs weaned and the liveweight, carcass traits and eating quality of terminal cross lambs. There was only a small impact of Merino rams on second cross lamb production. Prime lamb producers will be able to improve prime lamb production by sourcing ewes that have the right phenotype to produce first cross and terminal crossbred lambs. The data collected in this project has also been used in the development of a single Merino database to provide breeding values for Merino producers in traits important for prime lamb production.

Executive summary

Merino genes play an important role in prime lamb production in Australia. Approximately 26% of the 43 million Merino ewes in Australia were mated to non-Merino type rams with the intention of producing prime lamb in 2004-2005 (Martin 2004). However there is little knowledge of the effects of Merino ewes in prime lamb production systems. The aim of this project was to extend the outcomes from the Maternal Central Progeny Test (LAMB.325A) and determine the effect of Merino maternal genetics on prime lamb production.

Merino ewe progeny from the 2001, 2002 and 2003 South Australian Merino Central Test Sire Evaluation were retained for several years to measure reproductive traits, in addition to wool production and quality traits. These Merino ewes were mated to maternal (Border Leicester) and terminal sires (Poll Dorset). The Border Leicester cross ewe progeny were also mated to terminal sires to produce second cross lambs. All second cross, terminal cross and male Border Leicester cross lambs were grown out and then slaughtered in a commercial abattoir. Live animal and carcass traits were measured on all of these sheep to determine the effect of Merino rams on prime lamb production.

Merino genes do influence prime lamb production in commercial enterprises. Merino rams have an impact on the growth and health, carcase weight and eating quality of prime lambs; this effect was strongest in terminal crossbred lambs. Prime lamb production can be improved by:

- Mating Merino ewes whose fathers have high post weaning weight ASBVs. This will increase pre-slaughter liveweights of the first and terminal crossbred lambs. In this project, there was a 6kg difference at approximately 300 days of age in terminal cross grand progeny of different Merino rams.
- Mating terminal sires to Merino ewes whose fathers have desirable ASBVs for fat and EMD. There was a 4mm phenotypic difference between merino ram progeny groups in EMD and 1mm phenotypic difference between merino ram progeny groups in fat depth.
- Mating Merino ewes with similar ASBVs to create more consistent lines of prime lambs.

There were no significant correlations between terminal crossbred lamb carcase characteristics and Merino ram ASBVs for PWWT, FAT, EMD, HCFW, HFD, AFD and NLW.

Reproductive performance of Merino ewes is a major profit driver in prime lamb production systems. Number of lambs weaned (NLW) can be increased by:

- Mating Merino ewes whose fathers have high NLW ASBVs. This will result in increasing the genetic potential of number of lambs weaned through improved conception rates. This is particularly important for the production of first cross ewes that will be mated to produce second cross lambs.
- Mating terminal sires to Merino ewes whose fathers have high ASBV for HFAT and HWT. Merino ewes whose sires have HFAT ASBVs greater than 0.5mm weaned 10% more lambs compared to ewes whose fathers have low fat ASBVs.
- Mating heavy hogget Merino ewes.
- Mating older Merino ewes. Older Merino ewes had higher number of lambs weaned due to fewer dry ewes and increased conception rates.

There was no antagonism between prime lamb production and any of the Merino selection indices or ASBVs. Prime lambs can successfully be produced from Merino ewes that are sourced from ram breeders with wool orientated breeding objectives. This may actually improve the profitability of the prime lamb enterprise by increasing the wool income from the Merino ewes without adversely affecting production of prime lambs. Furthermore, Merino rams with high ACFW ASBVs produced terminal cross grand lambs with tender loins.

This project was conducted as part of a national MLA-supported program evaluating Merino genetics in the prime lamb industry. A comprehensive dataset of both standard and hard to measure traits such as eating quality and reproductive ability have been included in the Sheep Genetics database. The Merino rams used in this project also provided linkage between several Merino databases which has been used in the development of a single Merino genetic database.

Prime lamb producers, particularly producers of terminal crossbred lambs, will benefit from these results by understanding the impact the Merino ewe will have on the profit drivers of their prime lamb productions system. The Merino ewe affects both the number of lambs weaned and their slaughter weight, two of the major drivers affecting profit in prime lamb production systems.

Processors can benefit from these results through producers supplying lambs that better fit into the abattoirs requirements. Consistently meeting market requirements will improve profitability of both the prime lamb producer and the processor. There was considerable variation between prime lamb progeny groups and this will have an impact on achieving an even and consistent line of prime lambs. Prime lamb producers that wish to achieve an even line of lambs, generally select terminal sires with similar ASBVs. If attention is paid to sourcing Merino ewes that have similar liveweight, fat and EMD ASBVs there is likely to be less variation in their lambs.

As well as carcase weight and fat ranges, consumer appeal is also an important factor in keeping consumers satisfied and thus retaining or increasing market share. Consumers can also benefit from these results if prime lamb producers are able to take advantage of the variation that Merino rams contribute to loin tenderness.

Research Team

Scientists

Dr Janelle Hocking Edwards
Dr Nick Edwards
Dr Peter Speck
Dr Raul Ponzoni
Dr Geoff Hinch

Research Officers

Ms Rachael Gould
Ms Tamara Starbuck
Mr Adam Price
Ms Liz Abraham
Ms Katrina Copping
Ms Deb Rees

Farm Staff

Mr John Cooper
Mr Colin Windebank
Mr Shane Walker
Mr Gavin Scott
Mr James Stewart

Slaughter Team

In addition to above
Mr Darryl Smith
Mr Ben Hebart
Dr Michelle Hebart
Mr Paul Blackburn
Mr Mick Deland
Ms Carolyn Hilton
Tatiara Meat Company and their staff, particularly Mr Dale Cameron

Administration Staff

Ms Kelly Midwinter
Ms Bec McGennisken
Ms Tanya Biggins

Table of Contents

1 Background

Since the early 1990's, there has been strong genetic improvement in growth and carcass traits of terminal sires used in prime lamb production (Banks 2002). More recently, the Maternal Central Progeny Test (MCPT) demonstrated that there is considerable genetic variation between maternal sires that can be exploited to improve productivity and profitability of prime lamb enterprises (LAMB.325A). For example, there was a 45% range in number of lambs weaned among different maternal sire groups of first cross ewes and a 4kg range in liveweight between second cross lambs (Fogarty *et al.* 2005a). Merino genetics also play an important role in prime lamb production in Australia. Approximately 26% of the 43 million Merino ewes in Australia were mated to non-Merino type rams with the intention of producing prime lamb in 2004-2005 (Martin 2004). Furthermore, Merino ewes produced 60% of the lambs for slaughter and only 29%of the lambs for slaughter were produced from Border Leicester x Merino ewes. This demonstrates the preference for first cross rather than second cross lamb production by Australian lamb producers. Nevertheless, the value of Merino genes to prime lamb production is undefined to the commercial lamb producer and there is little knowledge of the effect of individual Merino sires on carcase traits or meat quality in crossbred lambs.

Merino genes are likely to have a significant impact on prime lamb production as there is considerable genetic variation between Merino sires in reproductive, growth and meat production traits in pure Merinos (Fogarty *et al.* 2003; Safari *et al.* 2007). This project was initiated to extend the results from the MCPT and focus on the impact of the Merino ewe and her sire in prime lamb production systems.

The hypothesis that Merino sires have an impact on prime lamb production was tested by utilising the South Australian Merino Central Test Sire Evaluation (CTSE). Merino CTSEs have been conducted nationally since 1987 and in the 2001 to 2003 evaluations in South Australia, an "enhanced" evaluation of the CTSE was offered to ram breeders by providing the option of evaluating the progeny for a range of additional traits associated with Merino production systems, including prime lamb production. The Merino ewe progeny from the CTSE were retained for several years to measure maternal traits, in addition to wool production and quality traits. In addition, a producer group associated with a livestock agency identified three Merino properties from which they would purchase ewes or Merino rams for their prime lamb enterprise. Assuming stocking rate is optimised, income drivers in commercial prime lamb production systems include number of lambs sold, carcase weight of the lamb and price/kg. Aspects such as genetics, reproduction, health and eating quality influence each of these factors. The effects of Merino genes on these factors in prime lamb production systems are presented in this report.

This project was conducted as part of a national MLA-supported program evaluating Merino genetics in the prime lamb industry. Since 2003, several projects and services (Merino Central Test Sire Evaluation, Merino Validation Project, Merino Genetic Services and Elders NEXT) have been providing data to estimate genetic parameters and breeding values for meat, wool, reproduction and disease traits in Merinos. The Merino rams used in this project provides linkage between the various databases. In addition, the data collected in this project will provide a comprehensive set of measurements of hard to measure traits such as eating quality and reproductive ability. This dataset will therefore assist in the development of a single Merino database to provide breeding values for Merino producers in traits important for prime lamb production.

From the viewpoint of commercial prime lamb producers, rather than seedstock producers, there is little information on how to identify ewes that will have most impact on their prime lamb production system. Through the push of ram breeders, prime lamb producers are beginning to embrace the use of ASBVs to select terminal and maternal sires for their enterprises. However, there is little, if any emphasis placed on informed selection of the ewes to which the prime lamb sire will be mated. Merino rams are often marketed as being ideal for the production of ewes for the prime lamb industry because they are bigger, leaner, fatter etc. than their counterparts. Likewise, Merino ewes are often purchased for prime lamb enterprises based on their size or other perceptions that they will make better prime lamb dams. And in other systems, the prime lamb dams are the cull or older ewes from a Merino wool enterprise. However, optimal strategies to select Merino ewes for prime lamb production are not well documented. Given that there is an increasing usage of ASBVs in the sheep industry, this project examines how Merino ASBVs can be used by commercial prime lamb producers and what other ewe selection strategies will optimise prime lamb production.

2 Project objectives

- Improved lamb production through greater awareness of the influence of Merino genes on prime lamb production in commercial enterprises.
- Greater accuracy in genetic evaluation of meat related traits due to improved estimates of phenotypic and genetic parameters.
- Information on the compatibility between wool, meat and reproductive oriented breeding objectives for Merino sheep.
- Information that can be used to improve carcasses and meat quality of first cross lambs which better fit market requirements.

3 Methodology

3.1 Experimental design

The detailed experimental design of this project is shown in Appendix 9.1 Briefly, the daughters of 34 Merino rams entered into the SA CTSE in 2001, 2002 and 2003 were naturally mated to produce cross bred lambs. The Merino ewes were mated to Border Leicester rams to produce "**maternal**" cross lambs (BLxMo) and to Poll Dorset rams to produce "**terminal**" cross lambs (PDxMo; Figure 3.1). These crossbred lambs were grown out and slaughtered and growth, health and carcase characteristics were measured. Maternal cross ewe lambs were retained and mated to Poll Dorset rams to produce **second** cross lambs (PDxBLxMo). The second cross lambs were also slaughtered and live animal and carcase information was collected.

The experiment was designed to test the hypothesis that there is an impact of Merino genes on prime lamb production. The Merino rams in the SA CTSE provided the genes of interest in this project. Thus, the effect of Merino genes on prime lamb production was determined by assessing the reproductive performance of Merino ewe progeny of known rams and evaluating the performance of the crossbred lambs produced by these Merino ewes. Therefore the Merino "genes" that are focussed on in this report originate from the maternal grand sires of the first cross lambs and the maternal great grand sires of the second cross lambs.

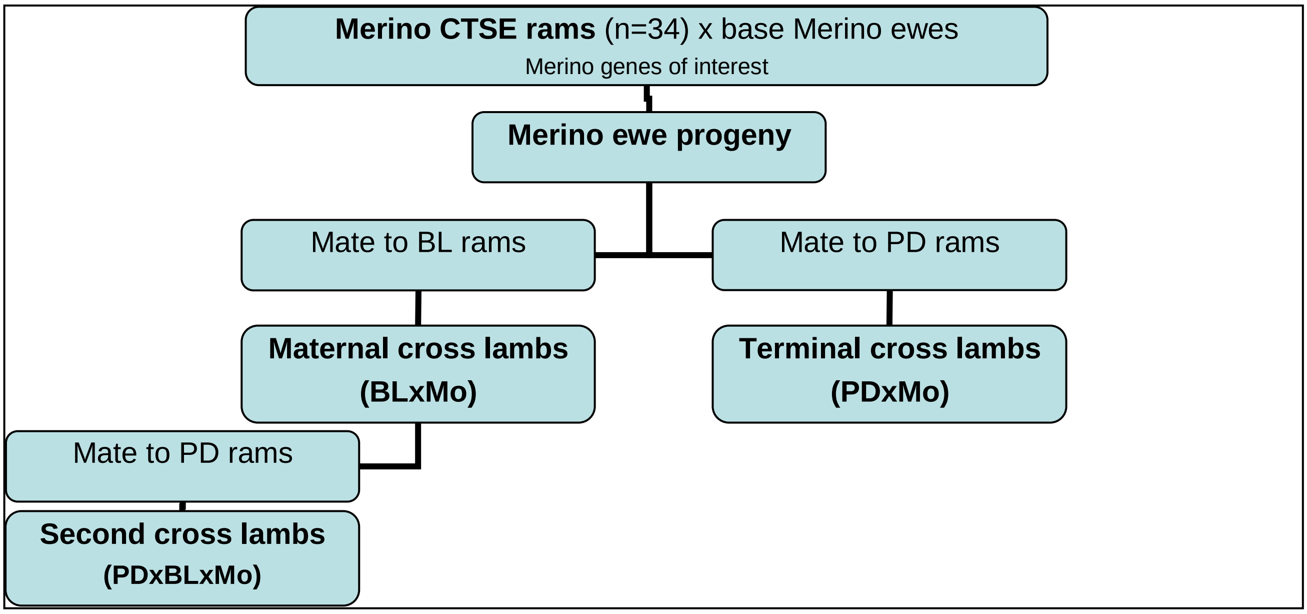


Figure 3.1. Simple experimental design of SHGEN027

Throughout the report, **progeny sire** refers to the actual sire of the sheep being discussed i.e. the Border Leicester sires (N=12) of the maternal cross progeny and the Poll Dorset sires of the terminal (N=13) and second cross progeny (N=8). **Merino ram/sire** refers to the original Merino rams containing the Merino genes of interest i.e. the Merino rams from the SA CTSE.

3.2 Location and seasonal conditions

The experiment was conducted at Kybybolite and Struan Research Centres (37 10'S; 140 48'E) in the south east of South Australia between January 2001 and June 2007 with approval from the PIRSA Animal Ethics Committee.

Struan and Kybybolite Research Centres were in drought conditions at various times during this project. These conditions had a major impact on this project during the autumn period of 2005 when it did not rain until mid June and pasture subsequent growth was very low (Figure 3.2) due to low soil temperatures. Lambing of the Merino ewes started in early June 2005 and the ewes were being 100% supplementary fed. There was no pasture of any value in the lambing paddocks and the ewes were fed grain until the end of lambing. In 2006, the season started well with a normal break in April. Ewes lambed on to green pastures with adequate feed, however there was little follow up rain and many frosts that impacted on spring pasture growth resulting in 30% of normal pasture production.

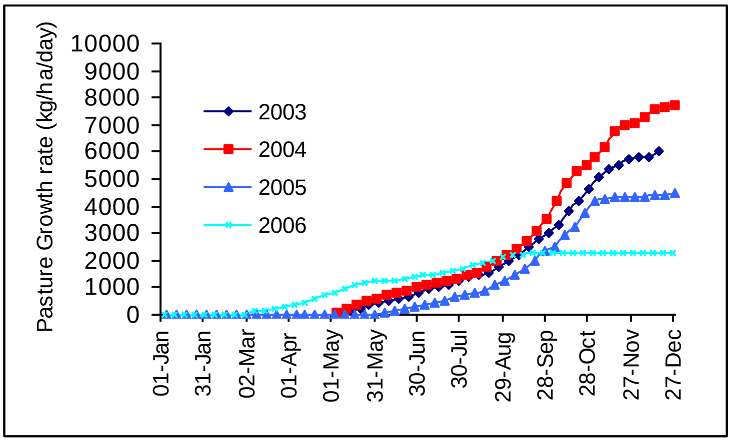


Figure 3.2. Cumulative pasture yields for Naracoorte/Lucindale District Council Area 2003, 2004, 2005 & 2006 Source data: Pastures from Space – graph prepared by Sean Miller and Katrina Copping, SARDI

3.3 Production of Merino ewes

Base Merino ewes were inseminated with semen from rams entered into the SA CTSE in 2001, 2002 and 2003 and the Merino ewe progeny produced for the CTSE were used in this project. A total of 34 rams were mated to a base ewe flock of South Australian type Merino ewes from 10 properties as part of the SA CTSE and produced 929 female progeny (Table 3.1). Two sires from the 2001 evaluation were used as link sires in 2002, a different sire from the 2001 evaluation was used as a link sire in 2003 and one sire from 2002 was used as a link sire in 2003.

Table 3.1 Number of Merino rams evaluated and number of Merino ewe progeny produced per year.

	2001	2002	2003	Total
Rams	10	15	13	34
Ewe progeny	310	353	542	1205

All Merino semen was supplied by ram breeders who chose to have the female progeny from the SA CTSE evaluated for lamb production, with the exception of six rams in 2003. These six rams were selected based on their EBVs to provide a range in breeding values as part of MLA project "Interaction between Merino genes and environment and their effect on prime lamb production - SHGEN.028". A portion of the 2003-drop Merino ewes were managed separately in the SHEGEN.028 project and are not included in this report.

There was a large amount of genetic variation between the Merino rams in key production traits (Appendix 2). For example there was a 64% range in number of lambs weaned (NLW) ASBVs, an 18kg range in hogget weight (HWT) ASBV, 31% range in hogget clean fleece weight (HCFW) ASBV and 4.5um range in hogget fibre diameter (HFD; Table 3.2).

Table 3.2. Minimum, maximum and range between 34 Merino rams ASBVS calculated by SGA in July 2007 for number of lambs weaned (NLW), maternal weaning weight (MWWT), post weaning weight (PWWT), post weaning fat (PFAT), hogget weight (HWT), fat depth (HFAT), clean fleece weight (HCFW) and fibre diameter (HFD). These ASBVs were calculated using the ewe progeny data and all other related data in the SGA database at that time.

Merino ram ASBV	NLW (%)	MWWT (kg)	PWWT (kg)	PFAT (mm)	HWT (kg)	HFAT (mm)	HCFW (%)	HFD (um)
Minimum	-14.5	-1.93	-2.93	-1.46	-5.46	-1.67	-5.42	-3.12
Maximum	50.5	2.91	13.2	1.77	13.14	1.92	26.03	1.53
Accuracy (%)	57-90	80-97	81-98	61-96	88-98	79-97	86-98	89-99

3.4 Production of prime lambs

The 2001 (Appendix 9.1.1) and 2002 (Appendix 9.1.2) drop Merino (Mo) ewes were naturally mated to Border Leicester (BL) rams at 20 months of age. The resultant first cross ewe lambs (BLxMo) were then mated to Poll Dorset (PD) rams at 9 months of age and then annually until 2006. This resulted in 3 drops of second cross lambs (PDxBLxMo) containing genes from the 2001 SA CTSE sires and 2 drops of second cross lambs containing genes from the 2002 SA CTSE sires (Table 3.3). The 2001 and 2002-drop Merino ewes were mated to PD rams at 3 years of age to produce terminal cross lambs (PDxMo). All of the 2003-drop Merino ewes were mated at 20 months and three years of age to PD rams to produce terminal cross lambs (Appendix 9.1.3).

Table 3.3. Year of birth (YOB) of Merino ewes that were subsequently mated to Border Leicester rams (BLxMo) and Poll Dorset rams (PDxMo). The resulting BLxMo ewes were mated to Poll Dorset rams (PDxBLxMo). Month and year of birth and slaughter and number of lambs slaughtered (in parentheses) of first, terminal and second cross lambs are shown in the body of the table. Superscripts refer to the 1st, 2nd & 3rd mating to produce the particular cross

YOB	Time	BLxMo	PDxMo[1]	PDxMo[2]	PDxBLxMo[1]	PDxBLxMo[2]	PDxBLxMo[3]
2001	Birth	June 03	June 04	-	Sept 04	Sept 05	Sept 06
2002		June 04	Sept 05	-	Sept 05	Sept 06	-
2003		-	June 05	Jan 06	-	-	-
2001	Slaughter	May 04 (95)	May 05 (227)	-	July 05 (65)	May 06 (100)	May 07 (107)
2002		May 05 (111)	June 06 (289)	-	June 06 (28)	May 07 (97)	-
2003		-	May 06 (265)	Feb/Mar 07 (339)	-	-	-

All of the BL rams were purchased from a single stud in 2003 and 2004 and all PD rams were purchased from a single stud in 2004 and 2005. The BL rams were selected to have similar Border$ Index within year and the Poll Dorset rams were selected to have similar Carcase Plus Index within year (Table 3.4). EBVs and Indices of these BL and PD rams were calculated by LAMBPLAN and supplied by the ram breeder prior to the sale of the rams.

Table 3.4. Minimum, maximum and range of EBVs for weaning weight (WWT) number of lambs weaned for Border Leicester (BL) purchased in 2001 or 2002 and Poll Dorset (PD) rams purchased in 2002 or 2003 and their Border$ (B$) or Carcase Plus (C+) Index

	WWT (kg)		HWT (kg)		YFAT (mm)		YEMD (mm)		NLW (%)		B$ Index	
BL	**2001**	**2002**	**2001**	**2002**	**2001**	**2002**	**2001**	**2002**	**2001**	**2002**	**2001**	**2002**
Min	0	0.7	1.9	1.4	-1.1	0.1	-0.6	0.0	0.9	4.7	104.0	107.0
Max	1.0	1.1	3.5	3.4	0.4	0.5	0.5	0.4	9.4	7.5	105.5	107.6
	WWT (kg)		**PWWT (kg)**		**PFAT (mm)**		**PEMD (mm)**				**C+ Index**	
PD	**2002**	**2003**	**2002**	**2003**	**2002**	**2003**	**2002**	**2003**			**2002**	**2003**
Min	3.5	4.2	5.5	6.4	-0.6	-0.9	-0.1	0.2			155	167
Max	4.9	6.2	9.3	9.6	0.3	-0.6	2.0	1.6			157	172

Adult Merino and first cross ewes were placed with testosterone-treated wethers for 14 days and then divided into groups of 37-43 ewes by stratified randomisation based on Merino ram, liveweight and birth type. First cross ewe lambs were weaned at 80 days of age onto phalaris/sub clover pastures where they were maintained until mid-December when they were moved onto irrigated pastures. At 210 days of age, they were teased with testosterone-treated wethers for 20 days to stimulate follicle cycling. All ewes were naturally mated on dry pasture and supplemented when necessary to maintain weight.

One ram was placed with each group of ewes for three weeks and then each ram was rotated into a new group of ewes from week 3 to week 6 of mating. When ewes were mated a second or third time to produce a particular cross (eg first cross ewes from the 2001 Merino drop were mated three times to PD rams – Table 3.3), they were mated to the same pair of rams to which they had been previously mated. Full sibs were produced from the repeat matings so that the sire effect could be fitted in the analysis and to ensure consistency across years.

At the completion of mating, the rams were removed and all contemporary ewes were recombined into a single mob until lambing. The ewes were pregnancy scanned using real time ultrasound between 60 and 85 days after the rams were removed. Pregnancy status was recorded and all ewes remained as a single mob. The ewes scanned empty stayed with their pregnant counterparts.

One week prior to the expected commencement date of lambing, the ewes were drafted into groups based on their maternal Merino sire group and placed into separate lambing paddocks. Stocking rate and FOO were managed to provide equivalents amounts of feed for each group during lambing. Ewes were checked daily and lambs were tagged and weighed within 24h of birth. When lambing was complete the groups were recombined into a single mob and the lambs were weighed and marked at an average age of 6 weeks and weighed and weaned at an average age 12 weeks.

Fat score or condition score and liveweight of the ewes were measured 2 weeks prior to mating (when the teasers were placed with the ewes), at pregnancy scanning and at lamb weaning. Fat score was used to measure all first cross ewes and the 2001 drop Merino ewes and condition scoring was used for the 2002 and 2003 drop Merino ewes. Method of assessment of the Merino ewes changed from fat scoring to condition scoring due to the focus of condition scoring of Merino ewes in the Lifetime Wool Project.

3.5 Prime lamb live animal measurements

After weaning, the prime lambs were grown on irrigated pasture until slaughter at approximately 300d of age with the exception of the lambs born in 2006. The terminal cross 2006-drop lambs were grown on dryland pasture and then finished in a feedlot. These lambs were slaughtered in two batches with the heaviest half of the group slaughtered at 240 days of age and the remainder slaughtered at 270 days of age. The second cross 2006-drop lambs were grown on irrigated pasture until 240 days of age and then finished in a feedlot and slaughtered at 300 days of age.

After weaning and prior to drenching, faecal samples were collected from which worm egg counts (FWEC) were calculated by a commercial laboratory. Liveweights were recorded at six to eight weekly intervals and fat and eye muscle depth (EMD) of the lambs was measured using real time ultrasound scanning prior to slaughter. Lambs were also fat scored prior to slaughter.

3.6 Carcase measurements

A total of 1720 crossbred lambs were slaughtered at Bordertown, South Australia, by Tatiara Meat Company and the hot carcase weights (HCWT) were recorded by the abattoirs central system. Carcasses were hung in a 2^{o}C chiller for 20hrs and then the carcasses were weighed on a hanging scale and cold carcase weights (CCWT) were recorded. The HCWT of 250 carcasses were not recorded due to problems with collection of individual hot weights by the abattoir. CCWT were measured on all lambs slaughtered, thus only CCWT will be discussed further. On the sample of lambs that did have HCWT, the conclusions between hot and cold carcase weights agree, as would be expected. After weighing, GR thickness was measured with a GR knife 100mm from the spin along the 12^{th} rib and then the carcasses were cut between the 12^{th} and 13^{th} rib. Carcase eye muscle depth (cEMD) and width (cEMW) and fat thickness (c-fat) were measured at this site with digital callipers. The ultimate pH (pHu) of the loin was measured at three positions on the cut loin (TPS WP-80 pH-temp meter; ATC probe Ionode IJ44pH) 22-24 hours after slaughter. Approximately 100g of loin caudal to the cut was removed and allowed to bloom for 30 minutes before loin lightness (L*), redness (a*) and yellowness (b*) were measured (Minolta chromameter; CR300). In 2006 and 2007, the b* measurement was not within the normal range of measurements and these have not been reported. A small sub-sample of loin was removed from the cranial end of the sampled loin and frozen in liquid N_2 and stored at -20^oC for subsequent analysis of glycogen potential. The remaining loin sample was tightly wrapped in cling film and aged at 4^oC for a further 4 days. The pH of the loin was measured (pH120) and then the sample was rewrapped in cling film, frozen and stored at -20^oC for subsequent analysis of shear force.

Shear Force: Samples were trimmed to 65-70g, weighed and cooked at 70^oC from the frozen state hanging in a water bath (30min), cooled with cold tap water (30min), rinsed, dried with paper towel and reweighed. Samples were then cut using the two scalpels joined at a width of 0.66cm and another pair joined at 1.5 cm to give a rectangular block with a cross sectional area of 1cm^2 with muscle fibres running a right angles to this. The slices were sheared across the grain using a Lloyd Universal testing apparatus set up as a Warner-Bratzler shear device (Harris and Shorthose 1988).

Glycogen: Prior to analysis samples were trimmed of fat and connective tissue then homogenised (Ultraturex) in HCl (30mM) for 60s. The homogenised sample was frozen and then stored at –20^oC until analysis. Glycogen content was assayed after enzymatic digestion (modified from (Gardner *et al.* 1999)). Samples were thawed at room temperature and then incubated in duplicate with amyloglucosidase (Roche Diagnostics, Castle Hill, NSW) in acetate buffer (40mM) for 90 minutes at 37^oC. Blank samples were incubated without amyloglucosidase. Glucose concentration of the incubated samples was measured with a hexokinase kit (ThermoTrace; Noble Park, SA) using an autoanalyser (COBAS MIRA). Glucose standards (Sigma-Aldrich; Castle Hill, NSW) were used to convert the autoanalyser data to mg glycogen/g tissue. Lactate was measured on aliquots from the homogenised sample with a lactate kit (Sigma-Aldrich; Castle Hill, NSW) using an autoanalyser (COBAS MIRA). Lactic acid standards within the kit were used.

3.7 Statistical analysis

The **genetic variation** of the Merino ewe progeny, first cross ewe progeny (**Section 4.1.1**) and prime lambs (**Sections 4.1.2.1, 4.1.2.3 and 4.1.2.5**) was described by analysing the estimated breeding values. The breeding values were calculated by Sheep Genetics (SG) in July 2007 using all of the data collected in this project and all other related data in the Merino database. Breeding values calculated by SG that have across flock linkages are known as Australian Sheep Breeding Values (ASBVs). ASBVs for liveweight, health, live carcase and reproductive traits were the variables in a fixed effect model using REML (SAS 2002-2003). The fixed effects in the model were Merino ram and ewe birth year.

Phenotypic measurements of prime lamb growth, health and carcase traits were analysed in a fixed effect model using REML (SAS 2002-2003). FWEC was $\log_{10}$+25 transformed and back-transformed means and errors are reported. The objective of this analysis was to determine the influence of the Merino genes on prime lamb production (**Sections 4.1.2.2, 4.1.2.4, 4.1.2.6** and **4.2.2**). The main effects in the model were Merino ram, year of Merino ewes birth (2001, 2002, 2003), mating time (lamb, maiden, second), progeny sire, sex (female, wether) and rear type (single, multiple). Birth type replaced rear type as a main effect for birth weight and reproductive factors. Age was included as a linear covariate for carcase weight and cold carcase weight was included as a linear covariate for the other carcase measurements. Two-way interactions were included in the model and removed from the model if not significant ($P<0.05$). Maternal cross, terminal cross and second cross progeny were analysed separately as not all cross types were produced every year. This project was not designed to compare cross types as the results are confounded by dam age, time of birth, time of slaughter and, in some cases, finishing system. Least square means and their standard errors are presented in this report.

Analysis of variance was used to analyse phenotypic reproductive performance (**Section 4.1.3**). The number of pregnant ewes, conception rate and number of lambs weaned per 100 ewes mated (NLW) and survival were the variables in the model. Year of joining was used as the replicate. Mean liveweight and condition score at mating of the Merino progeny groups were included as covariates in the analysis of the effect of Merino ram on NLW but neither were significant covariates. The proportion of pregnant ewes from each Merino ram group was calculated from the ratio of the number of ewes scanned pregnant to the number of ewes from each Merino sire group that were mated in that particular year. Similarly, conception rate was calculated by summing the total number of foetuses present at scanning in each Merino sire group and dividing by the number of ewes present at mating. NLW was calculated by summing the total number of lambs present at weaning in each Merino sire group and dividing by the number of ewes present at mating and multiplying this by 100. Survival was calculated from the ratio of number of lambs weaned to the number of foetuses scanned in each Merino sire group.

The relationship between Merino ewe liveweight, fatness and reproduction was analysed in **Section 4.1.3.1**. The effect of Merino ram on Merino ewe liveweight and condition score at mating was analysed in a fixed effect model using REML (SAS 2002-2003). The main effects in the model were Merino ram, year of Merino ewes birth (2001, 2002, 2003), mating time (First, Second) and the two-way interactions. To determine the relationship between ASBVs and phenotypic measurement of ewe fat/condition at different ages, Pearsons correlation coefficients were calculated for individual Merino ewe phenotypic measures of fat and ABVS for FAT and NLW. To determine the relationship between progeny group reproductive traits and liveweight and fat/condition, least square mean liveweights and condition scores progeny group means were correlated with number of lambs weaned.

To simulate the impact of different methods of Merino ewe selection by commercial prime lamb producers on prime lamb production (**Section 4.1.3.3** and **4.3.1**), ewes were divided into quartiles (Flocks) based on ewe liveweight at hogget mating or the ASBVs of their Merino sire. The effect of Flock on ewe ASBVs and phenotypic reproductive data was analysed in a fixed effect model using REML (SAS 2002-2003). The main effects in the model were Flock and year of Merino ewes birth (2001, 2002, 2003). Two-way interactions were included in the model and removed from the model if not significant ($P<0.05$). Mating time (First, Second) was also included as a fixed effect in the analysis of the phenotypic reproductive data.

To determine the compatibility between wool, meat and reproductive orientated breeding objectives in Merino sheep (**Section 4.3**) two sets of selection indices calculations were analysed. Firstly, Merino ram indices were calculated by Merino Genetic Services (MGS) in October 2005 using data collected on the 2001, 2002 and 2003 drop Merino progeny to hogget age and all other related data contained in the database. This dataset only contained Merino data. Secondly, Merino ram indices were calculated by SG in July 2007 using data collected from the first, terminal and second cross lambs produced by the Merino ewes in SHGEN027 in addition to information from all of the Merino progeny and all other related data contained in the Merino database. Phenotypic least square means of prime lamb production traits were regressed against Merino ram ASBVs, MGS calculated indices and SG calculated indices to determine the relationship between traits important for Merino production and traits important in prime lamb production systems.

Individual carcase measurements were regressed on individual live animal measurements to determine the relationship between live animal measurements and carcase measurement in crossbred lambs (**Section 4.4**). Progeny group least square means of carcase characteristics of terminal crossbred lambs estimated in section 4.2 were compared to the Merino EBVs and selection indices calculated by MGS in October 2005 and Merino ram ASBVs and selection indices calculated in the Merino SG database in July 2007. Pearson correlation coefficients are reported.

4 Results and discussion

4.1 Improved lamb production through greater awareness of the influence of Merino genes on prime lamb production in commercial enterprises.

4.1.1 Genetic variation of Merino ewes and their first cross daughters

To describe the genetic variation of the Merino and first cross ewe progeny the ASBVs for liveweight, health, live carcase and reproductive traits were analysed. A total of 1205 Merino ewe progeny and 241 first cross ewe progeny were assessed in this project. The number of Merino and crossbred ewes in each Merino ram progeny group is shown in Appendix 9.3.

Individual Merino ewes varied considerably in their ASBVs (Table 4.1.1a) demonstrating the large genetic variation that exists within the Merino ewe population. In this project, the ewe with the highest NLW ASBV has the potential to raise 50% more lambs in her lifetime than the ewe with the lowest NLW ASBV. Likewise there was a 6kg range in MWWT ASBVs, a 17kg range in PWWT ASBVs, a 3.5mm range in PFAT ASBVs, a 19kg range in HWT ASBVs, a 4.4mm range in HFAT ASBVs, a 35% range in HCFW ASBVs and a 6um range in HFD ASBVs.

Merino sire had a significant effect on their daughters ASBVs for NLW, MWWT, HWT, HFAT, HCFW and HFD (P<0.0001; Table 4.1.1b). There was a 35% range between Merino rams in their daughters mean NLW ASBV, a 2.9kg range in MWWT ASBVs, a 10.3kg range in HWT ASBVs, a 3.4mm range in HFAT ASBVs, a 15.9 % range in mean HCFW ASBVs and a 2.7um range in HFD ASBVs. There was no effect of year on the ASBVs for NLW but there was a significant effect of year on MWWT (P<0.001), HWT (P<0.0001), HFAT (P<0.0001), HCFW (P<0.0001) and HFD (P=0.002) ASBVs. This is due to the differences between Merino rams entered into the CTSE each year.

Table 4.1.1 Mean, standard deviation, minimum and maximum of ASBVs for number of lambs weaned (NLW), maternal weaning weight (MWWT), post weaning weight (PWWT), post weaning fat depth (PFAT), hogget weight (HWT), hogget fat depth (HFAT), hogget clean fleece weight (HCFW) and hogget fibre diameter (HFD) of (a) all Merino ewes and (b) Merino ewes combined into Merino sire groups

	NLW (%)	MWWT (kg)	PWWT (kg)	PFAT (mm)	HWT (kg)	HFAT (mm)	HCFW (%)	HFD (um)
(a) Merino ewe								
Mean	2.6	0.276	-0.78	-0.48	2.7	-0.04	9.65	-0.60
SD	7.77	0.893	3.32	0.59	3.68	0.808	6.488	0.865
Minimum	-11.3	-2.47	-8.22	-2.28	-6.9	-1.85	-8.10	-3.24
Maximum	39.0	3.53	8.91	1.28	12.1	2.55	26.43	2.82
(b) Progeny group								
Minimum	-6.7	-1.04	-5.42	-1.57	-1.95	-1.22	0.52	-1.96
Maximum	27.8	1.84	6.75	0.74	8.35	1.19	16.40	0.70

Individual first cross ewes varied considerably in their ASBVs (Table 4.1.2). The first cross ewe with the highest NLW ASBV has the potential to raise 37% more lambs in her lifetime than the ewe with the lowest NLW. Likewise there is a 7kg range in MWWT ASBV, a 17kg range in HWT ASBV and a 2.6mm range in HFAT ASBV.

Merino ram had a significant effect on mean ASBVs for first cross ewe progeny groups for NLW, HWT and HFAT (P<0.0001; Table 4.1.2b) but not MWWT ASBV. There was a 19% range in mean NLW ASBV, a 10.1kg range in HWT ASBV and a 1.6mm range in HFAT ASBV. There was no effect of birth year on the ASBVs for NLW or MWWT but there was a significant effect of birth year on HWT (P<0.0001) and HFAT (P<0.0001) ASBVs. There was no interaction between ram and birth year on any of the ASBVs analysed.

Table 4.1.2 Mean, standard deviation, minimum and maximum of ASBVs for number of lambs weaned (NLW), maternal weaning weight (MWWT), post weaning weight (PWWT), post weaning fat depth (PFAT), hogget weight (HWT), and hogget fat depth (HFAT) of (a) all Border Leicester x Merino ewe (first cross) and (b) first cross ewes combined into maternal Merino sire groups

	NLW (%)	MWWT (kg)	PWWT (kg)	HWT (kg)	PFAT (mm)	HFAT (mm)
(a) BL x Mo ewe						
Mean	5.70	1.19	-0.19	9.51	-0.47	0.90
SD	6.61	0.91	2.63	3.87	0.50	0.56
Minimum	-9.10	-2.85	-6.75	-0.03	-1.73	-0.33
Maximum	27.60	4.21	6.84	16.96	0.69	2.34
(b) Progeny group						
Minimum	-2.00	0.48	-2.74	3.41	-1.08	-0.02
Maximum	17.69	1.76	3.91	13.53	0.28	1.61

The range in ASBVs between individuals and between Merino ram progeny groups demonstrates the enormous amount of genetic variation that occurs as a result of Merino genes inherited from Merino rams. These ewes contain genes from their Merino fathers and grandfathers (in the case of the first cross ewes) that have the potential to impact on the number of lambs weaned and liveweight and fatness of prime lambs. For example, flocks of ewes from the ram with the highest mean NLW ASBV have the genetic potential to produce 35% more lambs. So in a flock that contains 1000 Merino ewes, there is the potential for an additional 350 prime lambs to be produced as a result of variation in Merino ram genetics. This is further transferred to the first cross ewes, although to a lesser extent as the impact of the Merino rams genes have been diluted by an extra generation. Nevertheless, there is the potential to produce an additional 190 lambs from a flock of 1000 first cross ewes that contain genes from Merino rams with the high NLW compared to a flock that contains genes for lower NLW.

Furthermore, the prime lambs produced by Merino ewes with high PWWT have the potential to be 6kg heavier at slaughter if slaughtered at similar ages or will reach slaughter at an earlier age. This has the potential to decrease feed costs.

4.1.2 Influence of Merino genes on prime lamb growth and health

Much focus has been placed on growth and health traits in both the maternal and terminal sires used in the prime lamb industry but little attention has been paid to the genes that are contributed through the Merino line. This section describes the genetic and phenotypic variation of prime lambs that can be attributed to the Merino genes from the maternal Merino grand sire on first cross and terminal cross lambs and great grand sire of the second cross lambs. The numbers of prime lambs that reached slaughter from each Merino ram progeny group are presented in Appendix 9.4.

4.1.2.1 Genetic variation of live animal traits of first cross lambs

Merino ram had a significant effect on first cross lamb ASBVS for birth weight, weaning weight, post weaning weight, PEMD, PFAT, WWEC and MWWT ($P<0.0001$; Table 4.1.3), demonstrating that the Merino genes can have a large impact on the genetic variation in first cross lamb traits.

Table 4.1.3,**Error! Reference source not found.** shows the least square mean ASBVs of first cross lamb progeny groups. There was a 4.7kg range in average post weaning weight and a 0.82mm range in fat depth between first cross lambs from ewes with the two extreme Merino sires. Similarly, there was a 3.1kg range in average post weaning weight and a 0.78mm range in fat depth between first cross lambs with the two extreme BL sires.

Table 4.1.3 Range in ASBVs of Merino ram first cross lamb progeny groups and Border Leicester (BL) sire first cross lamb progeny group (LSM ± SEM)

	Merino ram min	Merino ram max	BL sire min	BL sire max
BWT (kg)	-0.21 ± 0.030	0.23 ± 0.039	-0.14 ± 0.017	0.23 ± 0.019
WWT (kg)	-1.1 ± 0.23	1.0 ± 0.18	-1.0 ± 0.14	0.8 ± 0.20
PWWT (kg)	-2.0 ± 0.34	2.7 ± 0.27	-1.6 ± 0.25	1.5 ± 0.32
PEMD (mm)	-0.35 ± 0.067	0.54 ± 0.054	-0.25 ± 0.055	0.27 ± 0.064
PFAT (mm)	-0.79 ± 0.069	0.03 ± 0.052	-0.60 ± 0.063	0.18 ± 0.061
WWEC (epg)	-14 ± 3.3	32 ± 3.9	-34 ± 3.2	23 ± 2.4
MWWT (kg)	0.41 ± 0.126	1.65 ± 0.128	-0.09 ± 0.123	1.60 ± 0.089

The range in Merino progeny group ASBVs covers at least 50% of the spread of 2006 progeny in the MerinoSelect database as shown in the Merino Percentile Report (www.sheepgenetics.org.au/merinoselect). BL sire had a significant effect on first cross lamb ASBVS for birth weight, weaning weight, post weaning weight, PEMD, PFAT, WFEC and MWWT (P<0.0001; Table 4.1.3). The range in ASBVs between BL sire progeny groups was less than the range of ASBVs of the Merino grand sire progeny groups. This is despite the Merino grand sire only contributing ¼ of the genes to the first cross lambs.

4.1.2.2 Influence of Merino ram on phenotypic live animal traits of first cross lambs

Merino ram had a significant effect on the phenotypic measurement of birth weight (P<0.0001), weaning weight (P<0.0001) and liveweight at 300 days of age (P<0.0001) of first cross lambs (Table 4.1.4). Age was a significant covariate for weaning weight and 300-day liveweight and was included in the analysis. There was 1.3kg range between Merino rams in birth weight, a 5.3kg range between Merino rams in weaning weight and a 6.4kg range between Merino rams in liveweight at approximately 300 days of age of their first cross grand progeny. This range was larger than that predicted by the range of progeny group ASBVs (Table 4.1.1).

Table 4.1.4 Least square mean (± SEM) birth weight (Bwt), weaning weight (Wwt) and liveweight at approximately 300 days of age (D300wt), scanned eye muscle depth (EMD) and fat and faecal worm egg count (FWEC) for male, female, single and twin Border Leicester (BL) x Merino cross lambs. Single and twin are birth type effects on Bwt and rear type effects on Wwt and D300wt

	Bwt (kg)	Wwt (kg)	D300wt (kg)	EMD (mm)	Fat (mm)	FWEC (epg)
Merino ram min	3.8 ± 0.18	18.6 ± 0.92	41.7 ± 1.43	24.1 ± 1.24	2.8 ± 0.64	72 ± 1.61
Merino ram max	5.1 ± 0.25	24.7 ± 1.25	48.1 ± 1.37	27.6 ± 0.46	4.2 ± 0.24	595 ± 1.40
BL sire min	4.2 ± 0.10	20.4 ± 0.51	43.4 ± 0.91	26.0 ± 0.39	3.1 ± 0.47	135 ± 1.36
BL sire max	4.8 ± 0.12	22.4 ± 0.60	47.0 ± 1.11	27.0 ± 0.39	4.3 ± 0.21	382 ± 1.49
Female	4.2 ± 0.06	20.7 ± 0.34	41.8 ± 0.52	26.2 ± 0.32	3.8 ± 0.17	255 ± 1.15
Male	4.5 ± 0.07	22.2 ± 0.36	48.6 ± 0.56	26.6 ± 0.25	3.7 ± 0.13	291 ± 1.20
Single	4.9 ± 0.04	23.9 ± 0.20	46.4 ± 0.31	26.9 ± 0.19	3.9 ± 0.10	303 ± 1.11
Twin	3.9 ± 0.10	19.1 ± 0.57	44.3 ± 0.87	25.9 ± 0.40	3.6 ± 0.22	257 ± 1.28

There was no effect of Merino sire on the phenotypic measurements of EMD, fat depth or FWEC (Table 4.1.4), despite a significant Merino ram effect expected from the ASBV analysis (Table 4.1.3). There was a greater range between the extreme Merino sires in the measured EMD and fat depth than predicted from the range in ASBVs of these traits, however there was as much variation with Merino ram progeny groups as there was between Merino ram progeny groups. It is possible that even though there was sufficient genetic variation to be statistically significant when the ASBVs are analysed, there is so much environmental influence on the traits with smaller variation such as EMD and fat depth that this difference was not biologically significant.

BL sire had a significant effect on birth weight (P=0.005), liveweight at 300 days of age (P=0.01), fat depth (P=0.02) but not weaning weight, EMD or FWEC (Table 4.1.4). Single born lambs were heavier at birth than twin born lambs and single reared lambs were heavier than twin reared lambs at all liveweights (Table 4.1.4). Twin reared lambs had lower EMD (P<0.001) than single reared lambs, but there was no effect of rear type on fat depth or FWEC. Wether lambs were heavier than female lambs at all liveweights (Table 4.1.4) but there was no effect of sex on EMD, fat thickness or FWEC.

In first cross lamb production systems, use of Merino ewes with high ASBVs for liveweights are likely to produce first cross lambs with significantly higher liveweights than first cross lambs containing Merino genes for low liveweights.

4.1.2.3 Genetic variation of live animal traits of terminal cross lambs

Merino ram had a significant effect on terminal cross lamb ASBVs for birth weight, weaning weight, post weaning weight, PEMD, PFAT, WWEC and MWWT (P<0.0001; Table 4.1.5) demonstrating that the Merino genes can have a large impact on terminal cross lamb traits. Table 4.1.5 shows the least square mean ASBVs of terminal cross lamb progeny groups. There was a 4.3kg range in average post weaning weight and a 0.87mm range in PEMD between terminal cross lambs out of ewes from the two extreme Merino sires. The range in Merino progeny group ASBVs covers at least 50% of the spread of 2006 progeny in the MerinoSelect database as shown in the Merino Percentile Report (www.sheepgenetics.org.au/merinoselect).

Table 4.1.5. Range in ASBVs of Merino ram terminal cross lamb progeny groups and Poll Dorset (PD) sire terminal cross lamb progeny group (LSM ± SEM)

	Merino ram min	Merino ram max	PD sire min	PD sire max
BWT (kg)	0.03 ± 0.022	0.40 ± 0.033	-0.04 ± 0.010	0.33 ± 0.017
WWT (kg)	0.0 ± 0.21	2.3 ± 0.19	0.0 ± 0.19	2.1 ± 0.14
PWWT (kg)	-1.8 ± 0.35	2.5 ± 0.28	-0.9 ± 0.15	1.7 ± 0.26
PEMD (mm)	-0.11 ± 0.078	0.76 ± 0.057	-0.28 ± 0.070	0.97 ± 0.059
PFAT (mm)	-0.49 ± 0.062	0.54 ± 0.045	-0.58 ± 0.055	0.43 ± 0.047
WWEC (epg)	-4 ± 3.0	43 ± 3.6	6 ± 2.6	34 ± 1.4
MWWT (kg)	-0.82 ± 0.055	0.36 ± 0.062	-0.62 ± 0.063	0.24 ± 0.053

PD sire had a significant effect on terminal cross lamb ASBVs for birth weight, weaning weight, post weaning weight, PEMD, PFAT, WFEC and MWWT (P<0.0001; Table 4.1.5). The PD sires were selected to be as similar as possible to try and minimise the direct sire effect. However, with the exception of PWWT ASBV, the range in ASBVs between PD sire progeny groups was similar or greater than the range of ASBVs of the Merino grand sire progeny groups. These results suggest that there is more genetic variation in the PD rams than in the Merino rams and the PD rams are likely to have a much greater impact on the liveweight traits of terminal cross lambs which are important for prime lamb production.

4.1.2.4 Influence of Merino ram on phenotypic live animal traits of terminal cross lambs

Merino ram had a significant effect on birth weight (P<0.0001), weaning weight (P<0.0001) and liveweight at 300 days of age (P<0.0001) of terminal cross lambs (Table 4.1.6). Age at weighing was a significant covariate for liveweight and was included in the model. There was 1.3kg range between Merino rams in birth weight, a 7.2kg range between Merino rams in weaning weight and a 7.9kg range between Merino rams in liveweight at 300 days of age of their terminal cross grand progeny. As occurred with the first cross lambs, there was a much greater variation between Merino rams in actual liveweight traits than what occurred in the range of ASBVs between Merino rams. However, unlike what occurred in the first cross lambs, Merino ram also had a significant effect on EMD (P<0.001), fat thickness (P<0.0001) and FWEC (P=0.003; Table 4.1.6).

As would be expected, single born lambs were heavier at birth than twin born lambs (P<0.0001), and single reared lambs were heavier at all liveweights, had greater EMD and c-fat thickness than twin reared lambs (P<0.0001; Table 4.1.6). There was no effect of rear type on FWEC. Wether lambs were heavier than female lambs at all liveweights (P<0.0001; Table 4.1.6) and female lambs were fatter (P<0.001). There was no difference in EMD or FWEC between male and female lambs. Lambs born to ewes from their first mating to Poll Dorset rams were lighter, had smaller EMD, lower c-fat thickness and higher FWEC than lambs born to ewes at their second mating to Poll Dorset rams (P<0.0001). There was a significant effect of Poll Dorset ram on birth weight (P<0.0001), weaning weight (P=0.015) and liveweight at 300 days of age (P<0.0001). Poll Dorset sire did not affect FWEC, but had a significant effect on EMD (P<0.0001) and fat depth (P=0.002).

Table 4.1.6. Least square mean (± SEM) birth weight (Bwt), weaning weight (Wwt) and liveweight at approximately 300 days of age (D300wt), scanned eye muscle depth (EMD) and fat and faecal worm egg count (FWEC) for female, male, single and twin Poll Dorset (PD) x Merino cross lambs and PDxMo lambs born to ewes at their first or second mating. Single and twin are birth type effects on BWT and rear type effects on Wwt and D300wt

	Bwt (kg)	Wwt (kg)	D300wt (kg)	EMD	fat	FWEC
Merino ram min	3.8 ± 0.19	19.2 ± 0.98	34.6 ± 1.55	24.5 ± 0.69	1.6 ± 0.21	273 ± 1.45
Merino ram max	5.1 ± 0.18	26.4 ± 0.87	42.5 ± 1.32	28.3 ± 0.45	2.6 ± 0.15	907 ± 1.38
PD ram min	4.1 ± 0.07	21.8 ± 0.75	37.3 ± 1.12	25.0 ± 0.35	1.8 ± 0.14	298 ± 1.21
PD ram max	4.7 ± 0.16	23.9 ± 0.66	41.0 ± 1.13	27.4 ± 0.46	2.4 ± 0.13	545 ± 1.25
Female	4.3 ± 0.05^{a}	22.5 ± 0.25	37.3 ± 0.74	26.2 ± 0.28	2.3 ± 0.05	467 ± 1.12
Male	4.5 ± 0.05^{b}	23.3 ± 0.27	39.7 ± 0.73	26.2 ± 0.29	2.2 ± 0.05	487 ± 1.12
Single-born	4.9 ± 0.05^{a}	25.4 ± 0.22	40.2 ± 0.69	26.7 ± 0.25	2.3 ± 0.04	446 ± 1.11
Twin-born	3.9 ± 0.06^{b}	20.3 ± 0.34	36.8 ± 0.81	25.8 ± 0.34	2.1 ± 0.07	509 ± 1.15
First mate to PD rams	3.8 ± 0.06^{a}	21.2 ± 0.34	28.5 ± 1.40	24.2 ± 0.51	1.4 ± 0.07	1040 ± 1.22
Second mate to PD rams	5.0 ± 0.04^{b}	24.6 ± 0.22	48.5 ± 0.32	28.3 ± 0.15	3.0 ± 0.04	218 ± 1.06

As occurred in the first cross lambs there was a greater range in the phenotypic expression of the Merino genes in terminal cross lambs than that which was predicted from the progeny group ASBVs. Merino ram had a significant impact on both ASBV and expression of liveweight, fat and EMD in terminal cross lambs. Thus it is important to consider the Merino genes for liveweight, fat and EMD when producing terminal cross lambs. In this project, there was a 6kg difference at approximately 300 days of age in terminal cross between grand progeny of different merino rams. This has the potential to translate to significant increases in farm income.

4.1.2.5 Genetic variation of live animal traits of second cross lambs

Merino ram, BL ram and PD sire had a significant effect on second cross lamb ASBVs for birth weight, weaning weight (Merino; P=0.001), post weaning weight, PEMD, PFAT, WFEC and MWWT (P<0.0001; Table 4.1.7). BL ram had no effect on PFAT or PEMD. These results are the same as what was observed for effect of ram on average progeny group ASBVs in the terminal cross and first cross lambs. Surprisingly, there was a 4.1kg range in average PWWT ASBVs between Merino ram second cross lamb progeny groups which is similar to the 4.3kg range observed in the terminal cross lambs and 4.7kg range observed in the first cross lambs.

Table 4.1.7. Range in ASBVs of Merino ram second cross lamb progeny groups, Border Leicester (BL) ram second cross lamb progeny groups and Poll Dorset (PD) ram second cross lamb progeny groups (LSM ± SEM)

	Merino ram min	Merino ram max	BL ram min	BL ram max	PD sire min	PD sire max
BWT (kg)	0.06 ± 0.042	0.36 ± 0.067	0.16 ± 0.019	0.33 ± 0.023	0.10 ± 0.017	0.39 ± 0.022
WWT (kg)	0.6 ± 0.38	2.7 ± 0.59	1.0 ± 0.18	2.5 ± 0.22	0.2 ± 0.23	3.6 ± 0.17
PWWT (kg)	0.5 ± 0.58	3.6 ± 0.92	0.7 ± 0.28	3.2 ± 0.34	1.0 ± 0.35	3.7 ± 0.26
PEMD*	0.3 ± 0.10	1.0 ± 0.07	0.4 ± 0.08	0.7 ± 0.10	0.9 ± 0.10	-0.2 ± 0.05
PFAT*	-0.15 ± 0.069	0.38 ± 0.080	0.10 ± 0.062	0.29 ± 0.03	-0.5 ± 0.05	0.5 ± 0.04
WWEC	-2 ± 3.2	34 ± 5.1	-10 ± 3.4	19 ± 2.1	4 ± 2.7	25 ± 2.0
MWWT	-0.30 ± 0.097	0.21 ± 0.145	-0.66 ± 0.129	0.40 ± 0.070	-0.99 ± 0.065	0.58 ± 0.059

* Only 5 out of 8 PD rams PEMD and PFAT ASBVs are included as the accuracy was low for 3 of the PD rams.

4.1.2.6 Influence of Merino ram on phenotypic live animal traits of second cross lambs

Merino ram had a significant effect on birth weight (P=0.012), weaning weight (P=0.001) but not liveweight at 300 days of age of second cross lambs (Table 4.1.8). Age at weighing was a significant covariate for liveweight and was included in the model. There was 1.5kg range between Merino rams in birth weight and a 7.9kg range between Merino rams in weaning weight of their second cross great grand progeny. Merino ram did not affect EMD, fat thickness or FWEC.

Second cross single born lambs were heavier at birth than twin born lambs (P<0.0001), and single reared lambs were heavier than twin reared lambs at all liveweights (P<0.0001; Table 4.1.8). Single reared second cross lambs had greater EMD and fat thickness (P<0.0001). There was no effect of rear type on FWEC. Wether lambs were leaner (P=0.005) and heavier at birth (P=0.01), weaning weight (P<0.01) and post weaning weight (P<0.001; Table 4.1.8) than female lambs. Birth weight did not differ between lambs born to first cross ewes at their first, second or third mating to Poll Dorset rams but parity did have an effect on weaning weight, post weaning weight, fat depth, EMD and FWEC (P<0.0001).

Table 4.1.8. Least square mean (± SEM) birth weight (Bwt), weaning weight (Wwt) and liveweight at approximately 300 days of age (D300wt), scanned eye muscle depth (EMD) and fat and faecal worm egg count (FWEC) for female, male, single and twin second cross lambs and second cross lambs born to ewes at their first (lamb), second or third mating. Single and twin are birth type effects on BWT and rear type effects on Wwt and D300wt

	Bwt (kg)	Wwt (kg)	D300wt (kg)	EMD	fat	FWEC
Merino ram min	4.0 ± 0.30	24.7 ± 1.92	42.8 ± 2.00	26.8 ± 0.98	2.6 ± 0.32	126 ± 1.28
Merino ram max	5.5 ± 0.64	32.6 ± 4.40	51.4 ± 2.87	30.5 ± 0.50	3.9 ± 0.31	583 ± 1.48
PD ram min	4.4 ± 0.19	26.9 ± 0.69	40.8 ± 1.47	23.2 ± 0.59	1.0 ± 0.21	77 ± 1.27
PD ram max	5.5 ± 0.20	28.0 ± 1.06	50.0 ± 1.08	33.7 ± 0.62	4.8 ± 0.15	1085 ± 1.25
Female	4.8 ± 0.08	26.9 ± 0.43	45.9 ± 0.53	29.1 ± 0.24	3.4 ± 0.08	238 ± 1.10
Male	5.0 ± 0.08	28.1 ± 0.43	47.8 ± 0.54	28.7 ± 0.25	3.2 ± 0.08	216 ± 1.10
Single	5.3 ± 0.08	30.5 ± 0.40	49.2 ± 0.49	29.6 ± 0.23	3.5 ± 0.07	185 ± 1.10
Twin	4.5 ± 0.09	24.5 ± 0.49	44.5 ± 0.62	28.3 ± 0.29	3.1 ± 0.09	278 ± 1.12
Lamb mate to PD rams	5.0 ± 0.15	22.2 ± 0.88	41.1 ± 1.04	24.8 ± 0.53	2.1 ± 0.17	1106 ± 1.20
Second mate to PD rams	4.9 ± 0.08	28.5 ± 0.44	46.6 ± 0.56	27.5 ± 0.25	2.9 ± 0.08	225 ± 1.10
Third mate to PD rams	4.8 ± 0.12	31.8 ± 0.70	52.9 ± 0.83	34.5 ± 0.40	4.9 ± 0.13	32 ± 1.10

There was a significant effect of Poll Dorset ram on birth weight (P=0.002), liveweight at 300 days of age (P<0.0001), EMD, fat thickness and FWEC (P<0.0001), but not weaning weight. BL sire had a significant effect on EMD (P=0.003) but not fat or FWEC (Table 4.1.8).

These results indicate that even though there was significant difference between Merino rams in the ASBV of their second cross progeny group, there was so much within progeny group variation in the expression of the genes, that there was no significant difference in the phenotypic expression of the genes. Therefore, it is unlikely that Merino genes will have a major impact on liveweight at approximately 300 days of age, EMD or fat depth in second cross lambs, simply because only 1/8 of the genes it carries come from the maternal Merino grand ram. Any effect is diluted by the genes that the lamb has inherited from its other great grand parents, half of which originate from the Poll Dorset breed that has placed more emphasis on liveweight and will therefore have more opportunity to contribute to greater increases in liveweight and live carcase traits such as EMD and fat thickness.

4.1.2.7 Summary - Influence of Merino genes on live animal traits of prime lambs

Merino ram had a significant effect on the liveweight ASBVs of first, terminal and second cross lambs. This was translated into a significant effect of Merino ram on the phenotypic expression of liveweight at approximately 300 days of age in terminal and first cross lambs but not second cross lambs. Thus, to optimise first and terminal cross prime lamb production systems it is important to source Merino ewes whose fathers have high genetic potential for liveweight in order to maximise the liveweight of the prime lambs. However, despite a significant effect of Merino ram on second cross liveweight ASBVs, there was no effect of Merino ram on the phenotypic expression of liveweight at approximately 300 days of age. This indicates the impact of Merino genes in second cross lamb production is less important in affecting liveweight, primarily due to the dilution of the Merino genes in the second cross lamb.

Merino ram had an effect on PEMD, PFAT and WWEC ASBVs for all three crossbred lamb types indicating that there is significant variation between Merino rams in these traits, however, this was only expressed phenotypically in the terminal cross lambs.

There was considerable variation between prime lamb progeny groups and this will have an impact on achieving an even and consistent line of prime lambs. Prime lamb producers that wish to achieve an even line of lambs, generally select rams with similar ASBVs. However the ‘unknown’ Merino component can contribute a significant amount of variation to the production of the prime lambs, thus attention should be paid to sourcing Merino ewes which have similar liveweight, fat and EMD ASBVs so that there is not too much variation between their lambs.

4.1.3 Influence of Merino genes on number of lambs weaned

This section reports the phenotypic reproductive performance of the Merino ewes and describes the factors that contribute to differences in the number of lambs weaned. The impact of maternal Merino rams, Merino ewe liveweight and condition score and reproductive breeding values on reproduction of Merino ewes in prime lamb production systems is also described. Using this information, the data was modelled to predict the reproductive performance of ewe flocks if they were selected for prime lamb production based on the strategies described below.

Prime lamb producers are encouraged to select the terminal breed rams based on their genetic merit using ASBVs. However, the Merino ewes used in prime lamb production systems potentially come from a number of different sources. Some prime lambs producers select their ewes based on liveweight, with the perception that big Merino ewes make the best prime lamb mothers. Alternatively the Merino ewes may be cull ewes or older age groups from wool enterprises which are mated to terminal sires for their last few matings before being sold as cast-for-age ewes. Few prime lamb producers select Merino ewes based on the genes that are important for lamb production such as liveweight or NLW.

4.1.3.1 Phenotypic assessment of reproduction of Merino ewes

Merino rams influenced the number of lambs weaned from their daughters by affecting conception rate. There was a significant effect of Merino ram on the number of twins conceived by (P= 0.003), and the number of lambs weaned from (P< 0.001) their Merino daughters. There was a 66% range in conception rate between Merino ewes by different Merino rams resulting in 70% range in number of lambs weaned between ewe progeny groups (Table 4.1.9). This was much greater than expected based on the mean NLW ASBV of Merino rams progeny groups (Table 4.1.1).

Merino ram had no effect on the number of his daughters that became pregnant or the survival of his grand-progeny. These results demonstrate that Merino rams influence the reproductive ability of their daughters primarily through conception rate.

Table 4.1.9 Range between Merino rams of their daughters reproductive ability (Ram min/max) and average percentages across years and at 1st and 2nd mating opportunity of Merino ewes scanned pregnant, number of foetuses present at scanning/100 ewes mated (Conception), survival of lambs from scanning to weaning (Survival) and the number of lambs weaned/100 ewes mated (NLW) (standard error of the mean in parentheses)

	Ewes pregnant (%)			**Conception (%)**			**Survival (%)**			**NLW**		
Ram - Min	73 (7.5)			78 (12.0)			60 (9.7)			53 (8.8)		
Ram - Max	100 (7.9)			144 (12.0)			95 (10.2)			106 (8.4)		
	1st	**2nd**		**1st**	**2nd**		**1st**	**2nd**		**1st**	**2nd**	
2001	82	95	(4.7)	86	110	(6.1)	78	72	(4.2)	68	80	(5.3)
2002	86	94	(4.0)	92	118	(5.2)	78	76	(3.5)	72	90	(4.5)
2003	74	78	(4.7)	85	83	(6.2)	56	79	(4.3)	47	64	(5.4)

There were significant environmental effects on the number of lambs weaned (Table 4.1.9). Year of birth had a significant effect on NLW ($P<0.05$) with ewes born in 2003 having fewer lambs weaned than ewes born in 2001 or 2002. As expected, older ewes weaned more lambs ($P<0.001$) as a result of more ewes getting pregnant ($P<0.001$). More foetuses were conceived per ewe ($P<0.001$) at the second mating compared to the first mating.

There was no interaction between Merino ram, birth year or ewe age indicating that ranking of rams is similar across years and ewe age. However, there was a significant interaction between birth year and ewe age on conception rate ($P<0.001$; Table 4.1.9). Ewes born in 2001 and 2002 had a significant increase in number of foetus conceived at their second mating compared to their first mating but the ewes born in 2003 had no increase in conception rate at their second mating compared to their first mating. This is likely a result of drought conditions preventing the ewes regaining sufficient liveweight and condition after weaning of their lambs in 2005 and prior to mating in 2006. Likewise, there was a significant interaction between birth year and ewe age on survival ($P<0.001$). This was due to a significant increase in lamb survival of 2003-drop ewes as the ewes became older but there was no change in survival of lambs from the 2001 and 2002-drop ewes as they became older. The 2003-drop ewes lambed in early June 2005 at a time when the season had not broken and the ewes were being supplementary fed. There was no pasture of any value in the lambing paddocks and the ewes continued to be grain-fed until the end of lambing. Observations during lambing show that many of the ewes walked away from the lambs without ever mothering them. Basically, if the lamb did not follow the ewe immediately then it was left to fend for itself. This resulted in only 58% of lambs surviving from scanning to weaning. There was no interaction between birth year and mating age on NLW or the proportion of Merino ewes pregnant.

Generally, the 2001 and 2002-drop ewes performed similarly, however the 2003-drop ewes appear to have lower reproductive ability, which is likely to be an effect of the 2005 and 2006 drought conditions in which these ewes were assessed. As part of another experiment, the 2003-drop ewes were mated in 2007 and they achieved over 100% lambs weaned/ewe mated. Therefore, it is unlikely that there was a permanent environmental effect on these ewes; rather their poor performance was due to immediate environmental conditions and the Merino ewes were able to recover from adverse environmental conditions given adequate nutrition in subsequent seasons. The results from this trial indicate that the effect of Merino rams on their daughters' reproductive performance is consistent across different environmental conditions.

Merino rams had a significant effect on the genetic variation in reproductive performance of their daughters (Section 4.1.1). Merino ram ASBV was a good indicator of the reproductive performance of his progeny as there was a significant correlation between Merino ram ASBV and the phenotypic expression of number of lambs weaned from his daughters (r=0.745; Figure 2). This is not unexpected as Merino ram ASBVs were calculated using progeny records. However, Figure 2 also shows that the relationship is strongly affected by two outliers, indicating that the ASBV is correctly predicting the extreme ends of the traits.

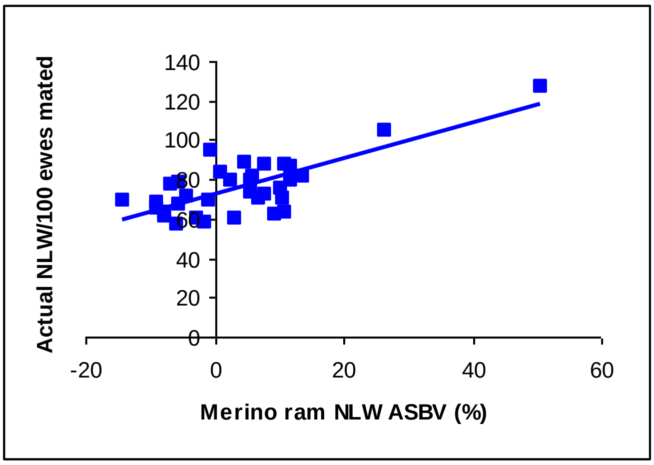


Figure 2. Relationship between Merino ram NLW ASBV and the actual NLW from his daughters

4.1.3.2 Phenotypic assessment of reproduction in first cross ewes

Merino ram did not influence the ability of his first cross grand daughters ewes to become pregnant, their conception rate, the proportion of first cross ewes that conceived twins or the number of second cross lambs weaned despite a significant effect of Merino ram on genetic variation of NLW ASBV (Section 4.1.1; Table 4.1.2b).

There was a significant effect of Merino ram on the survival of second cross lambs (P=0.017). This did not translate into an overall increase in number of lambs weaned and is unlikely to have a big impact, particularly as there was no effect of Merino ram on survival rate of lambs from the Merino ewes. Nevertheless, there may be some individual Merino rams that have significantly greater or lower survival of lambs and it may be useful to explore this further to detect any outliers to gain an understanding of the biology of lamb survival.

Reflecting the impact of non genetic effects on reproductive ability of the Merino ewes, age at mating affects reproductive performance of first cross ewes. First cross ewes mated at eight months of age had lower conception rate (P<0.0001), fewer twins (P=0.007), and fewer lambs weaned (P<0.0001) than first cross ewes mated at older ages. There was a significant year effect on number of lambs weaned from the first cross ewes (P=0.003).

4.1.3.3 Impact of Merino ewe choice on prime lamb production

4.1.3.3.1 Liveweight and condition score at mating

It is well established that phenotypic liveweight and condition score at mating are associated with conception rate within flocks of Merino ewes. For example, in mature Merino ewes, a 2.5 kg increase in liveweight was associated with a 5% increase in ovulation rate between 35 and 53 kg and there was a 10% increase per 2.5 kg between 40 and 48 kg (Edey 1968). The Lifetime Wool Project found that for each increase in condition score (approx 10kg liveweight) there was a 20% increase in conception rate. However this varied considerably between flocks and it was recommended that producers assess their flocks to determine how responsive the reproductive rate of their ewes is to increased liveweight or condition score (www.lifetimewool.com.au). It is possible that the differences in responsiveness of reproductive rate to increased liveweight or condition score reported by lifetimewool is genetic in origin.

The average genetic correlations between ewe weight and reproduction ranged from 0.46 to 0.78 with a mean value of 0.41 (reviewed by Fogarty 1995). More recently Safari *et al.* (2005) concluded that the genetic correlations for number of lambs born and weaned (per ewe joined) with weaning, post-weaning and adult weights were positive and moderate in magnitude. In Merinos, number of lambs weaned had a genetic correlation of 0.1 with bodyweight indicating that selection for an increase in bodyweight will have a positive effect on reproduction traits (Huisman and Brown 2008). In their review, Michels *et al.* (2000) concluded that the genetic relationship between reproductive performance and ewe weight, within breeds, may vary with body proportions in prolific and meat type sheep breeds as well as in differentially selected lines. However, the genetic correlation between litter and ultrasound fat depth at 14 months was −0.01 (Ap Dewi *et al.* 2002), suggesting that fat depth is poorly correlated with conception rate, at least in Welsh Mountain sheep. To date, there are no published genetic correlations between fat and reproductive traits in Merinos.

Although SHGEN027 was not designed to test the effect of genetics on the responsiveness of reproductive rate to changes in condition score or liveweight, it is possible to examine the relationship between Merino genes, ewe liveweight, condition score and reproductive rate in prime lamb production systems.

Merino ram, ewe birth year and ewe age affected phenotypic liveweight and condition score at mating (Table 4.1.10.) There was a significant effect of Merino ram on their daughters mean liveweight (P<0.001) and condition score (P<0.001) with a 10.6 kg range in liveweight and 1.0 unit range in CS between Merino ram progeny groups. There was no interaction between Merino ram progeny groups and either mating time or birth year for liveweight or condition score at mating.

Ewes born in 2001 were heavier at mating than those born in 2003 (P<0.005) which, in turn, were heavier at mating than those born in 2002 (P<0.001). Ewes born in 2001 had a higher condition score at mating than ewes born in 2002 or 2003 (P<0.001) and there was no difference in ewe condition score at mating between ewes born in 2002 and 2003. Ewes were lighter at their first mating compared to their liveweight at their second mating (P<0.001) and had a higher condition score at their first mating. There was a significant interaction between year of birth and mating time for both liveweight and condition score at mating (P<0.001; Table 4.1.10). Least square mean liveweights and condition scores have been included as covariates in subsequent analysis as these account for the between year variation that occurred.

Table 4.1.10 Mean liveweight and condition score at 1st or 2nd mating of Merino ewes born in 2001, 2002, or 2003 (standard error of the mean in parentheses)

Birth year	**Liveweight (kg)**		**Condition score**	
Mating	**1st**	**2nd**	**1st**	**2nd**
2001	41.1	51.9 (0.47)	3.1	3.1 (0.05)
2002	39.6	42.1 (0.39)	2.5	2.5 (0.05)
2003	42.3	46.5 (0.50)	2.9	2.4 (0.05)

NLW per 100 Merino ewes mated per year was significantly correlated with mean progeny group liveweight (r=0.474; Figure 3a) and condition score (r=0.620; Figure 3b) at mating. However there was a large range in NLW/100 ewes mated for any given liveweight or condition score. For example when the average condition score at mating was 2.75 or 3.0, there was a range of more than 20 NLW/100 ewes mated between different Merino ram progeny groups at both condition scores (Figure 3b). A similar range exists at any given liveweight at mating. This indicates that liveweight or condition score at mating is a reasonable predictor of reproductive ability – heavier ewes or fatter ewes tend to wean more lambs, however, between Merino ram progeny groups, liveweight or condition score cannot be used as an absolute indicator of reproductive performance.

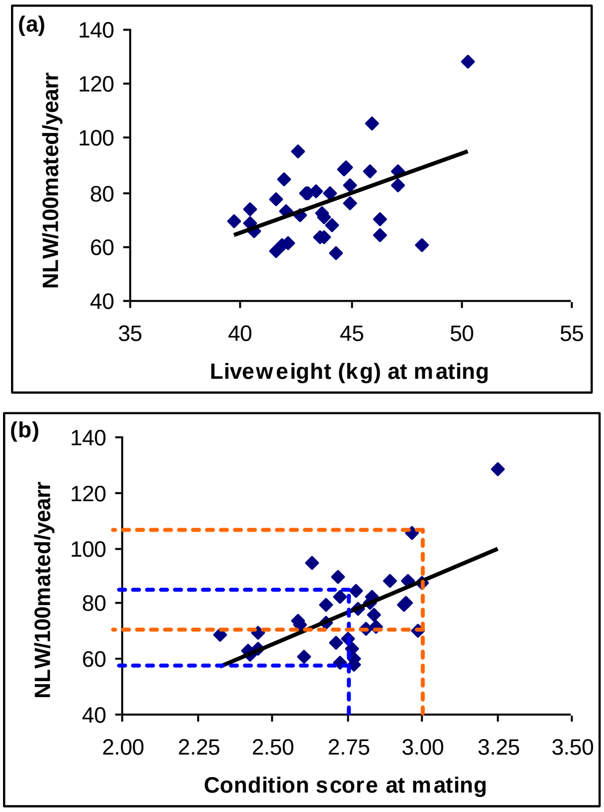


Figure 3. Effect of Merino ram progeny group (a) liveweight and (b) condition score at mating on the number of lambs weaned per 100 Merino ewes mated

Individual ewe FAT and NLW ASBVS were correlated with fat depth measured with real time ultrasound prior to hogget shearing (approx 480 days of age), fat score at mating and mid-pregnancy in Merino ewes (Table 4.1.11), with the exception that HFAT ASBV was not correlated with fat score at her first mating (approx 560 days of age). Condition score at mating and mid pregnancy were also correlated with FAT and NLW ASBVs, although PFAT ASBV was not correlated with ewe condition score at the second mating. Condition score at weaning was not correlated to FAT or NLW ASBVs. These results demonstrate that the FAT ASBVs are associated with both fat and condition scores of Merino ewes prior to and during pregnancy. Therefore, ewes with high FAT ASBVs will generally have higher condition or fat scores than ewes with low FAT ASBVs. There is also a flow on effect, in that ewes with high FAT ASBVs tend to have high NLW ASBVs, further demonstrating the relationship between ewe fatness and reproductive performance.

Table 4.1.11. Number of Merino ewes and correlation between FAT and NLW ASBVS, ultrasound fat thickness, fat scores and condition scores (CS) of Merino ewes at their first and second mating (Mate 1 & 2), Mid pregnancy (Mid preg 1 & 2) and lamb weaning (Wean 1 & 2)

	Timing	N	PFAT		YFAT		HFAT		NLW	
			r	P	r	P	r	P	r	P
cfat		2212	0.611	<0.0001	0.711	<0.0001	0.624	<0.0001	0.192	<0.0001
Fat score	Mate 1	754	0.619	<0.0001	0.467	<0.0001	0.019	ns	0.302	<0.0001
	Mid preg 1	307	0.464	<0.0001	0.520	<0.0001	0.410	<0.0001	0.497	<0.0001
	Mate 2	302	0.326	<0.0001	0.312	<0.0001	0.164	0.004	0.407	<0.0001
	Mid preg 2	170	0.401	<0.0001	0.362	<0.0001	0.250	0.001	0.363	<0.0001
CS	Mate 1	559	0.482	<0.0001	0.533	<0.0001	0.521	<0.0001	0.247	<0.0001
	Mid preg 1	929	0.364	<0.0001	0.338	<0.0001	0.212	<0.0001	0.224	<0.0001
	Wean 1	879	-0.144	<0.0001	-0.050	ns	-0.007	ns	0.028	ns
	Mate 2	830	0.060	ns	0.139	<0.0001	0.153	<0.0001	0.224	<0.0001
	Mid preg 2	1130	0.377	<0.0001	0.262	<0.0001	0.011	ns	0.267	<0.0001
	Wean 2	1097	0.132	<0.0001	0.063	0.036	-0.025	ns	-0.024	ns

In summary, there was a positive relationship between Merino ewe reproduction and phenotypic measurement of fatness/condition/liveweight at mating as well as with FAT ASBVs. This indicates that it is important to consider both genetic and phenotypic factors that contribute to the condition or fatness of ewes if trying to optimise reproductive performance of Merino ewes.

4.1.3.3.2 Selection of Merino ewes based on phenotypic liveweight

To simulate Merino ewe selection by commercial prime lamb producers, ewes were split into quartiles based on the on ewes' liveweight at hogget mating (Table 4.1.12).

Table 4.1.12. Number of ewes per simulated flock, mean and range of ewe liveweight at hogget mating used to select four flocks of ewes based on ewe liveweight at hogget mating over three years (2001 to 2003)

	2001			2002			2003		
Ewe liveweight	**N**	**Mean**	**Range**	**N**	**Mean**	**Range**	**N**	**Mean**	**Range**
Heaviest	75	47.9	44.5 - 56.5	84	46.4	44.0 –53.0	71	47.9	45.0 – 57.0
Mid-heavy	80	42.4	41.0 - 44.0	86	42.1	41.0 - 43.5	66	43.0	41.5 - 44.5
Mid-light	75	39.5	38.5 - 40.5	92	39.1	37.5 - 40.5	68	39.9	38.5 – 41.0
Lightest	80	35.0	24.0 – 38.0	91	34.4	27.0 –37.0	61	35.4	24.5 – 38.0

When the Merino ewes were divided into flocks ranked on their phenotypic liveweight at their first mating, there was a significant difference in average ASBVs for NLW ($P<0.0001$), MWWT ($P<0.0001$), HWT ($P<0.0001$), HFAT ($P<0.0001$), HCFW ($P<0.0001$) and HFD ($P<0.0001$) between the four flocks (Table 4.1.13) and between birth years. There was also a significant interaction between birth year and ewe flock on ASBVs for NLW ($P<0.0001$) and HWT ($P=0.001$) due to scale effects. There was an interaction between ewe flock and birth year in HFAT ($P<0.05$) and HCFW ($P<0.0001$) ASBVs due to re-ranking of ewe flocks across birth years.

The first cross ewe lambs from the heaviest Merino ewe flock had higher NLW, HWT and HFAT ASBV than the first cross ewes lambs from the lighter Merino ewe flocks ($P<0.001$; Table 4.1.13b).

Table 4.1.13. Least square mean ASBVS of (a) Merino ewes and (b) their BLxMo first cross daughters grouped into quartiles based on Merino ewe liveweight at first mating (standard error of the mean in parentheses)

(a) Merino ewes	NLW (%)	MWWT (kg)	HWT (kg)	HFAT (mm)	HCFW (%)	HFD
Heaviest quartile	7.98 [a]	0.58 [a]	5.5 [a]	0.18 [a]	8.7 [a]	-0.44 [a]
Mid-heavy quartile	2.68 [b]	0.32 [b]	3.1 [b]	-0.03 [b]	10.3 [b]	-0.57 [ab]
Mid-light quartile	0.85 [c]	0.11 [c]	1.7 [c]	-0.14 [b]	10.0 [b]	-0.70 [bc]
Lightest quartile	-1.11 [d]	-0.06 [d]	-0.1 [d]	-0.34 [c]	8.1 [a]	-0.83 [c]
SE	*0.43*	*0.51*	*0.15*	*0.07*	*0.37*	*0.052*

(b) First cross ewes	NLW (%)	MWWT (kg)	HWT (kg)	HFAT (mm)
Heaviest quartile	9.25 (0.68) [a]	1.40 (0.10)	10.3 (0.27) [a]	0.99 (0.014) [a]
Mid-heavy quartile	5.96 (0.72) [b]	1.10 (0.11)	9.2 (0.28) [b]	0.84 (0.044) [b]
Mid-light quartile	3.47 (0.80) [c]	1.09 (0.12)	8.4 (0.32) [bc]	0.75 (0.049) [b]
Lightest quartile	2.24 (0.91) [c]	1.11 (0.14)	7.7 (0.36) [c]	0.74 (0.055) [b]

There was a significant effect of Merino ewe liveweight group on number of Merino ewes' pregnant, conception rate of the Merino ewes, lamb survival and NLW for the Merino ewes (Table 4.1.14). Compared to the lightest flock, 20% more Merino ewes were pregnant at scanning, 38% more lambs were conceived and 10% more lambs survived, resulting in 37% more lambs weaned in the heaviest Merino ewe flock.

More first cross ewes born from the heaviest Merino ewes became pregnant, they conceived more lambs and more second cross lambs were weaned (Table 4.1.14). There was a significant interaction between ewe flock and mating age on the number of first cross ewes that became pregnant (P=0.0125) and conception rate in the first cross ewes (P=0.017). There was no effect of ewe flock on survival of lambs from the first cross ewes.

Table 4.1.14. Least square mean proportion of ewes pregnant, conception rate, lambs survival and number of lambs weaned per 100 ewes mated (NLW/100 ewes) from ewes grouped into quartiles based on Merino ewe liveweight at first mating

Merino ewe liveweight quartile	Ewes pregnant (%)	Conception (%)	Survival (%)	NLW/100 ewes
Heaviest quartile	92 [a]	114 [a]	76 [a]	86 [a]
Mid-heavy quartile	89 [a]	100 [b]	78 [a]	78 [b]
Mid-light quartile	84 [b]	92 [b]	72 [a]	67 [c]
Lightest quartile	71 [c]	76 [c]	64 [b]	49 [d]
SEM; Probability	*1.8; P<0.001*	*4.4; P<0.001*	*5.9; P=0.001*	*5.3; P<0.001*
First cross ewe progeny from Merino ewe flock				
Heaviest quartile	71	105	75	82
Mid-heavy quartile	71	97	82	81
Mid-light quartile	60	82	78	65
Lightest quartile	64	86	80	72
SEM; Probability	*5.0; P=0.03*	*8.1; P=0.015*	*4.6; ns*	*6.1; ns*

There was a significant interaction between weight group and mating period on number of ewes pregnant (P=0.004). This was due to a large increase in the number of ewes from the lightest group getting pregnant at their second mating compared to their first mating and no difference in the number of ewes getting pregnant at their first and second mating in the heaviest group. The two middle groups only had a slight increase in the number of ewes that became pregnant at their first and second matings. There was a significant interaction between birth year and mating period on conception rate (P=0.026) due to an increase in conception rate between first and second matings in the ewes born in 2001 and 2002 but no change in conception rate in ewes born in 2003. Lamb survival varied significantly between mating periods across birth years (P<0.001). There was a decrease in lamb survival between first and second mating in ewes born in 2001, no difference in lamb survival between mating periods in ewes born 2002 and an increase in lamb survival from ewes born in 2003 between their first and second lambing. There were no significant interactions between any of the factors on NLW.

4.1.3.3.3 Selection of Merino ewes based on sire HWT and FAT ASBV

When Merino ewes were divided into four flocks based on their sires' HWT ASBV (Table 4.1.15) the flocks that contained Merino ewes from rams with high HWT ASBVS conceived more lambs (P=0.011) and tended to wean more lambs (P=0.06) than flocks that contained ewes from rams with low HWT ASBVs (Table 4.1.15). However there was no difference in reproductive ability of the first cross ewes. Merino ewes born to rams with HFAT ASBV > 0.5mm conceived 10% more lambs (P=0.01) and tended to wean more lambs than ewes born to rams with HFAT ASBV <0.5mm (P=0.07). There was no effect of sire HWT or HFAT ASBVs on number of ewes pregnant or on lamb survival.

When Merino ewes were divided into four flocks based on their sires' MWWT ASBV there was no difference between flocks of any of the reproductive measures of the Merino ewes or their first cross daughters.

Table 4.1.15. Actual Merino ewe conception rate, NLW and NLW from their BLxMo first cross ewes lambs grouped into quartiles based on Merino ram hogget liveweight (HWT) and hogget fat (HFAT) ASBV ranked within year (standard error of the mean in parentheses)

		HWT ASBV Flocks				HFAT ASBV Flocks		
Ram ranking	**Ram ASBV range**	**Conception (%)**	**NLW (%)**	**NLW (%) First cross**	**Ram ASBV range**	**Conception (%)**	**NLW (%)**	**NLW (%) First cross**
Highest quartile	7.7 to 13.1	104 (3.5) [a]	75 (3.3) [a]	81 (6.6)	0.7 to 1.9	102 (4.0) [a]	74 (3.7) [a]	88 (6.6)
Mid – high quartile	1.6 to 5.0	98 (3.3) [ab]	74 (3.1) [ab]	77 (6.0)	-0.4 to 0.9	101 (3.3) [a]	75 (3.1) [a]	72 (6.0)
Mid – low quartile	-2.7 to 3.5	92 (3.5) [bc]	66 (3.3) [b]	84 (6.6)	-0.6 to -0.1	90 (3.1) [b]	65 (2.9) [bc]	79 (6.0)
Lowest quartile	-5.5 to 0.43	88 (3.3) [c]	65 (3.1) [b]	69 (6.4)	-1.7 to -1.5	91 (3.3) [b]	68 (3.1) [abc]	74 (7.1)

These results demonstrate that if prime lamb producers select their Merino ewes whose fathers have high HWT ASBVs or HFAT ASBVs greater than 0.5mm approximately 10% more lambs will be weaned from these ewes compared to ewes whose fathers have low ASBVs. However if these ewes are mated to Border Leicester rams, the first cross ewe progeny is unlikely to have higher reproductive potential.

4.1.3.3.4 Selection of Merino ewes based on sire NLW ASBV

To simulate different methods of Merino ewe selection by commercial prime lamb producers, ewes were split into flocks based on the ASBVs of their Merino sire or on ewes' liveweight at hogget mating (Table 4.1.16).

Table 4.1.16. Number of ewes per simulated flock, number of rams in parentheses, mean and range of (a) ram NLW ASBV (%) and (b) ewe liveweight (kg) at hogget mating used to select four flocks of ewes based on (a) ram NLW ASBV or (b) ewe liveweight at hogget mating over three years (2001 to 2003)

	2001			2002			2003		
(a) Ram NLW ASBV	**N**	**Mean**	**Range**	**N**	**Mean**	**Range**	**N**	**Mean**	**Range**
Highest	100 (3)	25.2	11.6 to 50.5	101 (4)	15.5	10.7 to 26.3	91 (4)	10.5	10.2 to 10.7
Mid-high	64 (2)	7.1	6.7 to 7.5	86 (4)	6.2	4.5 to 9.3	71 (3)	5.1	2.3 to 7.5
Mid-low	57 (2)	-6.4	-7.1 to -5.7	59 (3)	-0.3	-2.8 to 2.8	57 (3)	-0.6	-1.6 o 0.7
Lowest	89 (3)	-10.5	-14.5 to -8.0	106 (4)	-6.9	-8.0 to -5.6	47 (3)	-6.5	-9.3 to -4.6

When Merino ewes were classified into four flocks based on their fathers NLW ASBVs there was a significant difference in Merino ewe NLW ASBV (P<0.0001;). The ewes in the high NLW ASBV flock had a 14% higher mean NLW ASBV than the ewes in the low NLW ASBV flock. Merino ewes born in 2003 had a lower NLW ASBV than those born in 2002 (P<0.0001), which had a lower NLW ASBV than those born in 2001 (P=0.05). There was a significant year by flock interaction (P<0.0001) due to a difference in spread between flocks between years (Table 4.1.17).

Table 4.1.17 Mean NLW ASBV (%) of Merino ewes grouped into quartiles based on sire NLW ASBV ranked across years (All years) or ranked within years (2001 – 2003). Standard error of the mean in parentheses

Ram ranking	All years	2001	2002	2003
4.Highest quartile	9.9 (0.27)	15.6 (0.47)	8.6 (0.47)	5.5 (0.49)
3.Mid – high quartile	3.1 (0.32)	3.8 (0.59)	3.4 (0.51)	2.2 (0.56)
2.Mid – low quartile	-1.1 (0.36)	-2.6 (0.62)	-0.1 (0.61)	-0.7 (0.62)
1.Lowest quartile	-4.1 (0.32)	-5.5 (0.50)	-3.5 (0.46)	-3.4 (0.69)

Merino ewes in the high NLW ASBV quartile had greater MWWT (P=0.004), HWT (P<0.0001) and HFAT ASBV (P<0.0001) than Merino ewes in the lowest NLW ASBV flock (Table 4.1.18). The Merino ewes in the high NLW flock had lower HCFW (P<0.0001) and broader HFD ASBV (P=0.05) than the Merino ewes in the low NLW flock. There was a significant year effect (P<0.0001) and a significant year by flock interaction for MWWT, HWT, HFAT, HCFW and HFD ASBVs (P<0.0001).

Table 4.1.18 Mean ASBVs for maternal weaning weight (MWWT), hogget weight (HWT), hogget fat depth (HFAT), hogget clean fleece weight (HCFW) and hogget fibre diameter (HFD) of Merino ewes grouped into 4 groups based on sire NLW ASBV (standard error of the mean in parentheses)

Ram ranking	MWWT (kg)	HWT (kg)	HFAT (mm)	HCFW (%)	HFD (um)
Highest quartile	0.37 (0.045)	4.3 (0.16)	0.09 (0.04)	7.1 (0.31)	-0.57 (0.044)
Mid – high quartile	0.42 (0.051)	2.2 (0.18)	-0.10 (0.04)	9.7 (0.36)	-0.49 (0.051)
Mid – low quartile	-0.06 (0.058)	2.1 (0.21)	-0.14 (0.05)	9.8 (0.41)	-0.94 (0.057)
Lowest quartile	0.17 (0.052)	0.9 (0.18)	-0.31 (0.04)	11.3 (0.36)	-0.70 (0.051)

First cross ewes from the flock with high Merino ram NLW ASBV had higher NLW ASBV than all other flocks (; P<0.0001) and the flock with the second highest NLW ASBV had higher NLW ASBV than the two low NLW ASBV flocks (P<0.0001). There was no effect of NLW ASBV flock on MWWT ASBV, but there was a significant effect of flock on HWT (P=0.01) and HFAT ASBV (P=0.002;) of the first cross ewes. There was a significant year effect for NLW ASBV (P=0.02), HWT ASBV (P<0.0001) and HFAT ASBV (P<0.0001) and a significant flock by year interaction on HWT ASBV (P=0.014).

Table 4.1.19. Mean ASBVs for maternal weaning weight (MWWT), hogget weight (HWT) and hogget fat depth (HFAT), of first cross ewes grouped into quartiles based on maternal grandsire NLW ASBV (standard error of the mean in parentheses)

First cross ewes	NLW (%)	MWWT (kg)	HWT (kg)	HFAT (mm)
Highest quartile	10.4 (0.59)	1.26 (0.099)	9.7 (0.27)	0.95 (0.04)
Mid – high quartile	6.2 (0.67)	1.24 (0.113)	9.3 (0.32)	0.73 (0.05)
Mid – low quartile	1.3 (0.98)	1.32 (0.165)	8.8 (0.45)	0.76 (0.07)
Lowest quartile	1.7 (0.67)	1.00 (0.113)	8.3 (0.31)	0.87 (0.05)

This analysis demonstrates that prime lamb producers that use ewes from rams with the highest NLW ASBV will create ewe flocks that have high average NLW ASBVS compared to flocks of ewes from rams with lower NLW ASBVs. If the Merino ewe flock is mated to Border Leicester rams, the resulting first cross ewe flock will also have a higher mean NLW ASBV compared to first cross ewe flocks whose grandsire Merino rams had lower NLW ASBVs.

Merino ewes whose fathers had high NLW ASBVs actually conceived 17% more lambs and weaned 16% more lambs than ewes whose fathers had low NLW ASBVs (). Selecting Merino ewes based on their sires NLW ASBV did not affect the number of ewes that became pregnant nor the survival of their lambs. If ewes were divided into three flocks rather than four flocks based on their fathers ASBV the results do not alter, whilst the differences become slightly less between the three flocks.

Table 4.1.20. Actual reproductive values of Merino and first cross ewes grouped into quartiles based on Merino ram NLW ASBV (standard error of the mean in parentheses)

Merino ewes	**Ewes pregnant (%)**	**Conception (%)**	**Survival (%)**	**NLW/100 ewes mated**
Probability	ns	P<0.001	ns	P=0.003
Highest quartile	85 (2.0)	105 (2.7)	73 (2.1)	78 (2.7)
Mid – high quartile	86 (2.2)	97 (3.1)	73 (2.3)	70 (3.1)
Mid – low quartile	85 (2.3)	91 (3.2)	75 (2.5)	69 (3.2)
Lowest quartile	83 (2.0)	88 (2.8)	72 (2.2)	62 (2.8)
First cross ewes				
Probability	ns	P=0.05	ns	ns
Highest quartile	73 (3.7)	105 (6.5)	81 (4.7)	86 (6.0)
Mid – high quartile	64 (4.1)	90 (7.1)	82 (5.3)	75 (6.6)
Mid – low quartile	63 (4.4)	79 (7.6)	83 (5.5)	68 (7.1)
Lowest quartile	66 (3.7)	87 (6.5)	89 (4.6)	79 (6.0)

First cross ewes from flocks based on the NLW ASBV of their Merino ram paternal grand sire did not differ in number of ewes pregnant, lamb survival or number of lambs weaned. First cross ewes from the flock with the highest Merino ram NLW ASBV conceived 20% more lambs than the two flocks with the lowest NLW ASBVs (Table 4.1.21).

In summary, prime lamb producers that select their ewes based on Merino ram ASBVs will create ewe flocks that have the genetic potential to produce more lambs than if no attention was paid to Merino ram NLW ASBVs. As a result, these selected flocks will conceive more twins and wean more lambs per 100 ewes mated. These flocks will also generally have higher liveweight ASBVs, lower HCFW and broader HFD ASBVs. The trend in average ASBVs continues into the first cross ewe flock but is not expressed in the actual NLW from the first cross ewe flock.

4.1.3.4 Summary - Influence of Merino genes on number of lambs weaned

Merino genes do have an effect on reproductive performance in prime lamb production systems, particularly through the production of first cross and terminal cross lambs. There was a significant effect of Merino ram of the number of lambs weaned from his daughters, primarily through variation in conception rate rather than differences in the ability of the ewe to get pregnant or through lamb survival. Merino ram also affects liveweight and condition score – this is not unexpected due to differences in HWT and HFAT ASBVS. However including liveweight or condition score in the analysis did not remove the effect of Merino ram on reproductive performance suggesting that differences in reproductive performance due to Merino genes is not solely due to differences in liveweight or condition score, rather it is operating through a different pathway.

The Merino ram has an inconsistent effect on the number of second cross lambs produced. Nevertheless, the additional number of first cross ewes produced from a Merino ram source with high NLW would increase the number of first cross ewes that enter the second cross lamb system as dams. This would result in an additional economic benefit from Merino rams with high NLW. For example a Merino ram whose Merino daughters have 100%NLW will contribute twice as many first cross ewes as dams compared to a Merino ram that has 50%NLW. Then even if the first cross ewes both have 100% NLW there will still be twice as many second cross progeny from the Merino ram with the high NLW. Thus, an important aspect of Merino genes in prime lamb production regarding their reproductive ability is the numbers of first cross ewes that can be produced from a particular Merino ram source, although this effect would usually be fairly small.

This analysis demonstrates that prime lamb producers can have the biggest impact on Merino ewe reproductive ability by selecting the heaviest ewes at hogget mating for prime lamb production. This provides the best phenotype to maximise the number of lambs weaned by tending to select for ewes with high NLW ASBV as well as identifying those that have had a "fortunate" life, be it through rear type, nutrition, lack of disease or genetics. As prime lamb producers are interested in total number of lambs weaned rather than generational changes in number of lambs (ie NLW does not need to be heritable or passed onto the prime lamb that will be slaughtered), it is important to select the ewes with the ideal phenotype. Liveweight at hogget mating appears to be the best predictor of this. However, if the Merino ewes are used to produce first cross ewes, then a greater response in the number of lambs weaned from first cross ewe progeny will be achieved by selecting Merino ewes whose fathers have high NLW ASBV. Although there was no significant effect of selection strategy of Merino ewes on reproductive ability of their first cross ewe progeny, trends were evident that first cross ewes from Merino ewes selected based on their fathers NLW ASBV will have the greatest impact on reproductive ability of first cross ewes.

4.1.4 Conclusion - Lamb production can be improved through greater awareness of the influence of Merino genes on prime lamb production in commercial enterprises

Merino genes have a major role in the prime lamb industry and many Merino breeders market their rams and ewes as being ideal for prime lamb production systems. Number of lambs turned off and carcase weight are the major profit drivers in prime lamb production systems. This section has focussed on improving lamb production by understanding the role of Merino genes on these two profit drivers and tried to identify the types of Merinos most appropriate to prime lamb production. The Merino rams evaluated in this project were selected by ram breeders as potentially suitable to perform well in prime lamb production systems. There was a large range in the ASBVs of these rams with a 65% range in NLW, a 15kg range in PWWT and 3.2mm range in PFAT enabling any variation in the performance of the progeny in prime lamb productions systems to be detected if present.

Merino genes do influence prime lamb production in commercial enterprises. Prime lamb production can be improved by;

- Mating Merino ewes whose fathers have high NLW ASBVs. This will result in increasing the genetic potential of number of lambs weaned through improved conception rates. This is particularly important for the production of first cross ewes that will be mated to produce second cross lambs.
- Mating heavy hogget Merino ewes to increase the number of lambs weaned.
- Mating older Merino ewes to increase the number of lambs weaned. Older Merino ewes had higher number of lambs weaned due to fewer dry ewes and increased conception rates.
- Mating Merino ewes whose fathers have high PWWT ASBVs to increase post weaning liveweight of the first and terminal crossbred lambs. In this project, there was a 6kg difference at approximately 300 days of age in terminal cross between grand progeny of different merino rams.
- Mating Merino ewes whose fathers have high ASBV for fat and EMD in terminal cross lambs.
- Mating Merino ewes whose fathers have similar ASBVs to create more consistent lines of prime lambs.

4.2 Greater accuracy in genetic evaluation of meat related traits due to improved estimates of phenotypic and genetic parameters.

4.2.1 Improved estimates of genetic parameters of meat related traits

This project collected data to be included in the Sheep Genetics database to be used to increase the accuracy in genetic evaluation of meat related traits by improving the estimates of genetic parameters.

All phenotypic measures of carcase traits, including hot (HCWT) and cold carcase weights (CCWT), GR depth, loin eye muscle depth (cEMD), width (cEMW) and fat thickness (c-fat), loin ultimate pH, loin colour (L*, a*, b*), glycogen potential and loin tenderness have been submitted to Sheep Genetics for inclusion in the database. A summary of the submitted slaughter data is shown in Table 4.2.1.

Table 4.2.1. Number, average and standard deviation of carcase measurements of first cross (BL x Merino), terminal cross (PD x Merino) and second cross (PD x (BL x Merino)) lambs slaughtered

	First cross		Terminal cross		Second cross	
	N	Mean ± SD	N	Mean ± SD	N	Mean ± SD
HCWT (kg)	229	21.4 ± 3.37	687	21.0 ± 3.14	366	23.0 ± 4.04
CCWT (kg)	231	21.0 ± 3.04	835	20.7 ± 3.17	397	22.2 ± 4.07
GR (mm)	230	13 ± 4.9	834	12 ± 4.4	396	14 ± 5.8
cEMD (mm)	230	29 ± 3.4	835	29 ± 4.1	397	31 ± 4.3
cEMW (mm)	231	60 ± 4.2	835	60 ± 4.0	397	61 ± 3.7
c-fat (mm)	231	4.8 ± 1.96	835	4.1 ± 1.81	397	4.6 ± 2.08
L*	231	33.4 ± 2.69	833	34.3 ± 1.80	397	34.7 ± 2.47
a*	231	17.7 ± 1.61	833	17.6 ± 1.40	397	16.9 ± 1.41
b*	231	4.2 ± 1.60	833	3.0 ± 2.10	397	0.2 ± 1.33
Ultimate pH	231	5.65 ± 0.191	836	5.71 ± 0.20	397	5.81 ± 0.11

4.2.2 Phenotypic parameters of meat related traits

The effect of terminal and maternal sires on prime lamb carcase and meat related traits have recently been reported. Terminal sires selected on the basis of their LAMBPLAN EBVs produced crossbred lambs that reflect their breeding values for carcase traits (Hegarty *et al.* 2006b). The MCPT also found that maternal sires had a significant effect on hot carcase weight, carcase fat levels, and muscle dimensions, but not for meat colour and ultimate meat pH in first cross (Fogarty *et al.* 2005b) and second cross prime lambs (Afolayan *et al.* 2007). However, it is unknown whether the Merino genes in crossbred lambs impact on carcase related traits and if so, to what extent.

Less is known about the effect of genetics on sheep meat eating quality. Poll Dorset rams affect eating quality of first cross (Hocking Edwards *et al.* 2004) and second cross progeny (Hopkins *et al.* 2005a) and it is known that there is variation between eating quality of pure Merino, first cross and second crossbred lambs (Hopkins *et al.* 2005b). For example, carcases from Merinos generally tend to be darker and redder than other types of lamb carcases and it would follow that the greater the proportion of Merino in a lamb, the darker and redder the meat. The literature tends to support this although differences are not always significant (Hopkins *et al.* 2005b). First cross lambs tend to have higher ultimate pH than second cross lambs (Gardner *et al.* 1999) although not consistently (Hopkins *et al.* 2005b).

This section describes the phenotypic effect of Merino genes from the maternal Merino grand sire on first cross and terminal cross lambs and the Merino genes from the great grand sire on second cross lambs on meat related traits.

4.2.2.1 First cross lamb carcase and meat traits

Merino ram and BL sire had an inconsistent effect on first cross lambs meat related traits. Merino ram had a significant effect on GR ($P<0.001$), cEMD ($P=0.033$) but not on CCWT

(P<0.1), cEMW or c-fat (Table 4.2.2). BL sire had a significant effect on GR (P<0.0001) and cEMW (P=0.043) but not CCWT, cEMD or c-fat (P = 0.06). There was no effect of rear type on CCWT, cEMD or c-fat. Single reared first cross lambs had greater GR thickness (P<0.0001) and cEMW (P=0.005). There were no interactions between any of the main effects on carcase traits of first cross wether lambs. Age was a significant covariate for CCWT and CCWT was a significant covariate for GR, c-fat, cEMD and cEMW of first cross wether lambs.

Table 4.2.2. Least square mean (± SEM) cold carcase weight (CCWT), GR thickness, carcase eye muscle depth (cEMD) and width (cEMW) and fat for single and twin reared Border Leicester (BL) x Merino cross lambs and the range between Merino and BL ram progeny groups

	CCWT (kg)	GR (mm)	cEMD (mm)	cEMW (mm)	c-fat (mm)
Mo ram - min	18.8 ± 1.05	13.4 ± 1.42	26.4 ± 1.41	55.7 ± 1.49	3.5 ± 1.09
Mo ram - max	22.2 ± 0.25	19.0 ± 1.45	32.2 ± 1.85	63.8 ± 2.47	7.5 ± 0.74
BL sire - min	19.6 ± 1.16	13.1 ± 0.98	27.2 ± 0.87	56.9 ± 1.13	3.8 ± 0.81
BL sire – max	22.5 ± 0.72	18.8 ± 0.72	31.0 ± 1.37	61.3 ± 1.43	5.8 ± 0.42
Single	21.4 ± 0.25	13.7 ± 0.28	29.5 ± 0.29	60.5 ± 0.39	4.8 ± 0.17
Twin	20.5 ± 0.76	17.2 ± 0.86	29.7 ± 0.90	57.0 ± 1.20	4.9 ± 0.53

Merino ram and BL sire also had an effect on some of the objective eating quality measurements. There was a significant effect of Merino ram on pH at 24 hours post slaughter (P<0.001) and shear force of the loin (P=0.033) and there was a tendency for Merino ram to affect glycogen potential of the loin (P=0.06; Table 4.2.3). There was no effect of Merino ram on loin colour. BL sire had a significant effect on ultimate pH (P<0.0001), glycogen potential (P<0.0001), shear force (P=0.016), redness (P=0.002) and yellowness of the loin (P=0.029) but not darkness of the loin (Table 4.2.3). There was no effect of rear type on colour, ultimate pH, glycogen potential or tenderness of the loin.

Age was a significant covariate for lightness in colour of the loin and glycogen potential of the loin whereas CCWT was a significant covariate for loin redness of first cross wether lambs. There was a significant interaction between birth year and BL ram in the analysis of loin yellowness, a significant interaction between Merino ram and birth year in the analysis of ultimate pH and a significant interaction between Merino ram and BL sire in the analysis of ultimate pH and glycogen potential.

Table 4.2.3. Range in least square mean (± SEM) loin colour (lightness, redness and yellowness), pH 24h after slaughter, glycogen potential (g/100g muscle) and shear force (SF; kgF) Border Leicester (BL) x Merino cross lambs Merino and BL ram progeny groups

	Light (L*)	Red (a*)	Yellow (b*)	pH24	glycogen	SF
Mo ram - min	32.3 ± 0.73	16.9 ± 0.88	4.31 ± 0.737	5.37 ± 0.083	0.45 ± 0.075	2.84 ± 0.446
Mo ram - max	35.1 ± 0.85	18.8 ± 0.55	5.69 ± 0.634	5.73 ± 0.010	0.71 ± 0.078	3.91 ± 0.550
BL sire - min	32.8 ± 0.59	17.3 ± 0.51	4.23 ± 0.357	5.44 ± 0.047	0.49 ± 0.044	3.31 ± 0.308
BL sire – max	34.4 ± 0.40	19.3 ± 0.42	5.55 ± 0.322	5.71 ± 0.058	0.76 ± 0.036	4.42 ± 0.284

4.2.2.2 Terminal cross lamb carcase and meat traits

Merino ram and PD both had an impact of the terminal crossbred lamb carcase and meat traits. Both Merino ram and PD sire had a significant effect on CCWT (P<0.0001; Table 4.2.4) and GR (P<0.05). Merino ram affected cEMW (P=0.016) but not cfat nor cEMD. PD sire had a significant effect on cfat (P=0.015) and cEMD (P=0.025) but not cEMW. Single reared terminal cross lambs were heavier than twin reared lambs (P<0.0001), had thinner GR (P<0.0001) and larger cEMD (P=0 04). Male terminal cross lambs were heavier than female terminal cross lambs (P<0.0001), had thinner GR (P<0.0001), wider cEMW (P=0.0004) and less cfat (P<0.0001). CCWT was a significant covariate for GR, cfat, cEMD and cEMW. Age was also a significant covariate for cEMD. There was a significant interactions between year and Merino ram in the CCWT analysis, year and PD ram in the analysis of cfat and Merino ram and PD ram in the analysis of cEMW.

Table 4.2.4. Least square mean (± SEM) cold carcase weight (CCWT), GR thickness, carcase eye muscle depth (cEMD) and width (cEMW) and fat for female, male, single and twin reared Poll Dorset x Merino cross lambs and the range between Merino (Mo) and Poll Dorset (PD) ram progeny groups

	CCWT (kg)	GR (mm)	cEMD (mm)	cEMW (mm)	Cfat (mm)
Mo ram - min	18.5 ± 0.65	10.6 ± 0.88	58.9 ± 0.76	27.6 ± 0.86	3.3 ± 0.49
Mo ram - max	23.1 ± 0.52	13.6 ± 0.82	63.3 ± 0.94	30.4 ± 0.76	4.9 ± 0.33
PD sire - min	20.2 ± 0.26	11.3 ± 0.62	28.0 ± 0.70	59.5 ± 0.72	3.7 ± 0.29
PD sire – max	21.7 ± 0.24	13.2 ± 0.30	31.0 ± 1.02	61.6 ± 0.61	4.4 ± 0.29
Single	21.8 ± 0.14	11.7 ± 0.16	29.7 ± 0.16	60.6 ± 0.18	4.0 ± 0.09
Twin	20.2 ± 0.22	12.8 ± 0.27	29.0 ± 0.30	60.6 ± 0.32	4.1 ± 0.15
Female	20.5 ± 0.16	13.0 ± 0.20	29.5 ± 0.21	60.2 ± 0.23	4.3 ± 0.11
Male	21.6 ± 0.17	11.5 ± 0.20	29.2 ± 0.21	61.0 ± 0.23	3.7 ± 0.11

There was a significant effect of Merino ram on loin colour (P<0.001), glycogen potential (P<0.0001) and shear force of the loin (P=0.046). Contrary to the first cross lambs, there was no effect of Merino ram or PD ram on pH at 24 hours post slaughter in the terminal cross lambs. There was a significant effect of PD sire on lightness of colour and redness (P<0.05), glycogen potential (P<0.0001) and shear force of the loin (P<0.0001). Loins of males were lighter in colour (P<0.0001), less red (P<0.0001), had lower concentration of glycogen (P=0.04) and were tougher than females (P=0.002). Single reared lambs were lighter in colour than twins (P=0.003), but there was no effect of rear type on redness, yellowness, pH24, glycogen potential or shear force. CCWT was a significant covariate for loin colour and pH24 of terminal cross lambs. Age was also a significant covariate for pH24. There was a significant interaction between birth year and PD ram in the analysis of loin pH24, glycogen potential and shear force. There was a significant interaction between Merino ram and birth year in the analysis of shear force of loins from terminal cross lambs.

Table 4.2.5. Least square mean (± SEM) loin colour (lightness, redness and yellowness), pH 24h after slaughter (pH24), glycogen potential (g/100g muscle) and shear force (SF; kgF) for male and female Poll Dorset x Merino cross lambs and the range between Merino (Mo) and Poll Dorset (PD) ram progeny groups

	Light (L*)	Red (a*)	Yellow (b*)	pH24	glycogen	SF
Mo ram - min	33.5 ± 0.54	16.8 ± 0.32	1.9 ± 0.24	5.60 ± 0.034	0.63 ± 0.042	3.34 ± 0.361
Mo ram - max	35.3 ± 0.50	18.3 ± 0.27	2.8 ± 0.15	5.71 ± 0.035	0.87 ± 0.028	4.89 ± 0.405
PD sire - min	33.9 ± 0.16	16.6 ± 0.21	2.0 ± 0.16	5.64 ± 0.013	0.67 ± 0.028	3.31 ± 0.123
PD sire – max	35.3 ± 0.29	18.1 ± 0.12	2.5 ± 0.08	5.67 ± 0.014	0.82 ± 0.025	5.18 ± 0.264
Female	34.1 ± 0.11	17.7 ± 0.08	2.3 ± 0.06	5.65 ± 0.009	0.76 ± 0.010	3.76 ± 0.073
Male	34.7 ± 0.11	17.4 ± 0.08	2.4 ± 0.06	5.66 ± 0.009	0.74 ± 0.010	3.99 ± 0.076

4.2.2.3 Second cross lamb carcase and meat traits

Merino ram had a significant effect on second cross GR thickness (P=0.04) but no effect on CCWT, cEMD, cEMW or cfat thickness (Table 4.2.6). PD ram influenced CCWT (P<0.001), GR thickness (P=0.01), cEMD (P=0.03) and c-fat thickness (P<0.005) but not cEMW. There no effect of BL ram on CCWT, GR thickness, cEMD or cfat thickness but there was on cEMW (P=0.02). Second cross male carcasses were heavier than female carcasses (P<0.001). When adjusted for CCWT, second cross female carcasses were fatter at the GR site and at the eye muscle (c-fat; P<0.0001) and had a greater cEMD (P<0.001) but smaller cEMW (P<0.01) than male carcasses. Single reared lambs had heavier carcasses (P<0.001) than twin born lambs when adjusted for carcase weight but there was no difference between rear types in GR thickness or eye muscle measurements. Year of birth had a significant effect on CCWT (P<0.0001), GR thickness (P<0.0001), cEMD (P<0.0001) and c-fat thickness (P<0.001).

Table 4.2.6. Least square mean (± SEM) cold carcase weight (CCWT), GR thickness, carcase eye muscle depth (cEMD) and width (cEMW) and fat for female, male, single and twin reared second cross lambs and the range between Merino (Mo) and Poll Dorset (PD) ram progeny groups

	CCWT (kg)	GR (mm)	Cfat (mm)	cEMD	cEMW
Mo ram min	19.4 ± 0.99	11.1 ± 1.17	3.3 ± 0.43	27.3 ± 2.17	56.6 ± 1.49
Mo ram max	23.5 ± 1.54	14.2 ± 1.07	5.8 ± 0.69	32.3 ± 0.63	63.1 ± 0.76
PD ram min	19.8 ± 0.46	11.7 ± 0.90	3.8 ± 0.38	29.1 ± 0.95	58.5 ± 1.00
PD ram max	23.7 ± 0.90	14.6 ± 0.60	6.2 ± 0.57	31.8 ± 0.64	61.7 ± 0.67
Female	20.5 ± 0.37	13.7 ± 0.37	5.0 ± 0.24	30.9 ± 0.40	59.5 ± 0.42
Male	21.5 ± 0.38	12.1 ± 0.37	4.2 ± 0.24	29.9 ± 0.40	60.4 ± 0.42
Single-reared	22.2 ± 0.37	12.7 ± 0.36	3.4 ± 0.63	30.5 ± 0.38	60.0 ± 0.41
Twin-reared	19.8 ± 0.41	13.2 ± 0.41	4.9 ± 0.23	30.3 ± 0.43	59.8 ± 0.46

There was a significant effect of Merino ram on glycogen potential (P<0.0001) and shear force of the loin (P=0.017). There was no effect of Merino ram on darkness, redness or pH at 24 hours post slaughter. Loin lightness (P=0.009), glycogen potential (P<0.0001) and shear force (P<0.0001) was affected by PD sire. There was no effect of PD ram on loin redness, or pH at 24 hours post slaughter. There was no effect of BL ram on lightness, redness (P=0.06), pH at 24 hours post slaughter, glycogen potential (P=0.09) or shear force of second cross lambs. Males were lighter in colour (P<0.0001) and had lower concentration of glycogen in their loin (P=0.04) than females. There was no effect of rear type on any of the eating quality traits of the second cross lambs. CCWT was a significant covariate for loin redness and pH24 of second cross lambs. Age was a significant covariate for glycogen potential. There was a significant interaction between Merino ram and PD ram on loin redness and between birth year and PD ram on loin pH24 and shear force.

Table 4.2.7. Least square mean (± SEM) loin colour (lightness and redness), pH 24h after slaughter, glycogen potential (g/100g muscle) and shear force (SF; kgF) for male and female second cross lambs and the range between Merino (Mo), Border Leicester (BL) and Poll Dorset (PD) ram progeny groups

	Light (L*)	Red (a*)	pH24	glycogen	SF
Mo ram - min	31.6 ± 1.38	16.1 ± 0.53	5.70 ± 0.046	0.65 ± 0.098	2.33 ± 0.580
Mo ram - max	35.8 ± 0.74	17.9 ± 0.61	5.86 ± 0.021	0.92 ± 0.094	5.26 ± 0.368
BL ram – min	33.6 ± 0.41	16.1 ± 0.41	5.78 ± 0.023	0.74 ± 0.062	3.25 ± 0.485
BL ram - max	34.9 ± 0.43	17.2 ± 0.33	5.83 ± 0.023	0.91 ± 0.062	4.73 ± 0.333
PD sire - min	33.0 ± 0.42	16.3 ± 0.32	5.76 ± 0.032	0.72 ± 0.044	3.14 ± 0.492
PD sire – max	34.9 ± 0.62	17.2 ± 0.44	5.84 ± 0.024	0.90 ± 0.068	4.46 ± 0.225
Female	34.0 ± 0.25	16.9 ± 0.19	5.79 ± 0.013	0.83 ± 0.027	4.00 ± 0.203
Male	34.4 ± 0.25	16.7 ± 0.19	5.80 ± 0.013	0.80 ± 0.028	4.28 ± 0.208

4.2.2.4 Conclusion - Phenotypic parameters of meat related traits

Merino, BL and PD ram all have the potential to impact on carcase traits of prime lambs, although the effects were inconsistent across types of crossbred lamb. PD ram affected CCWT in both the terminal and second cross lambs; however the Merino ram only had an impact on CCWT in the terminal cross lambs (range of 4.6kg between extreme progeny groups) and the effect was tending towards significance in the first cross lambs. This indicates that there is an impact of maternal Merino grand sire on CCWT but by the second cross, the Merino genes of interest have been diluted enough not to have an effect by the second cross progeny who only carry 1/8 of the original genes of interest. BL ram did not affect CCWT in either the first cross or second cross. This is not unexpected as the rams were selected to have similar PWWT EBVs, which is likely to result in similar CCWT.

Lean meat yield was not measured as part of this project but the significant differences in GR thickness and c-fat suggest that there may be some Merino ram effect on lean meat yield.

Merino ram inconsistently affected the objective measures of eating quality. Shear force, ultimate pH and glycogen potential were all affected by Merino ram in the first cross wether lambs. These are linked through biochemical processes and it is possible that there maybe Merino genes affecting this pathway. However, contrary to preliminary results presented in SHGEN027 Milestone 7 Report there was no significant effect of Merino ram on pH in the terminal cross progeny. CCWT and age removed the Merino ram variation, as when CCWT and age were omitted from the model, Merino ram had a significant effect. There was a significant negative correlation between ultimate pH and CCWT (r=-0.466) in the terminal cross lambs, indicating that heavier carcasses tend to have lower pH. A similar correlation existed in the second cross lambs (r=-0.455) but not in the first cross lambs (r=-0.013).

Both Merino and PD ram had an effect on loin shear force and glycogen potential in all of the crossbred lambs and BL ram had an impact on these two measures in the first cross lambs but not the second cross lambs. This indicates that there is likely to be considerable variation between rams in loin tenderness and glycogen potential.

4.3 Compatibility between wool, meat and reproductive oriented breeding objectives for Merino sheep.

In prime lamb production systems that use the Merino ewe as the base ewe, the performance of the ewe potentially has a significant impact on the profit drivers of the prime lamb business. She has a major impact on wool income and, as demonstrated in section 4.1 and 4.2 of this report, she has an effect on the number of lambs weaned and the liveweight and carcase traits of first cross and terminal cross lambs. It is a traditionally held belief that there is antagonism between wool, meat and reproductive orientated Merino breeding objectives. SHGEN027 provided the opportunity to examine the impact of different breeding objectives on prime lamb production. The relationship between Merino ram ASBVs and prime lamb production were also examined.

Two sets of index calculations were analysed in this section. Firstly, Merino ram indices calculated by MGS containing only Merino data represents the information most likely to be available to a prime lamb producer when Merino ewes are selected for prime lamb production. Secondly, Merino ram indices calculated by SG containing all data Merino and crossbred data collected in this project was used to represent the most “accurate” indices and breeding values as they contain the most information available about the rams of interest and their progeny.

4.3.1 Wool breeding objectives and prime lamb production

Several wool orientated breeding indices have been calculated by MGS and SG. Least square mean progeny group liveweights were regressed on the various Merino ram wool breeding indices to determine the relationship between wool orientated breeding objectives and prime lamb growth.

The MGS 20%MP Index was negatively correlated with first cross lamb birth weight (r=-0.489; P=0.02) and weaning weight (r=-0.442; P=0.039). This indicates that using Merino ewes from rams with high 20%MP will result in lower birth weight and weaning weight of first cross lambs. However, there were no significant correlations between MGS 20%MP Index and First cross lamb liveweight at 300 days of age. Furthermore there were no significant correlations between the MGS 20%MP Index and liveweight of terminal or second cross lambs nor any significant correlations between the MGS 8%MP and liveweight of any crossbred lambs. There were no significant correlations between the Merino ram SG 7%Merino, SG 10%+SS or SG 14%+SS Indices and first cross, terminal cross or second cross lamb liveweights. There was a significant correlation between first cross birth weight and ACFW ASBV (r=-0.429; P=0.04) and also between first cross weaning weight and Merino ram AFD ASBV (r=0.438; P=0.04). There was no relationship between Merino ram wool ASBVs and first cross liveweight at approximately 300 days of age, terminal cross liveweights or second cross liveweights.

These results indicate that there is unlikely to be any effect, either positive or detrimental, on liveweights of crossbred lambs born to ewes whose fathers were selected for improved wool production. The only exception to this is if very high emphasis is placed on decreasing fibre diameter such as occurs in the MGS 20%MP Index, there may be a decrease in crossbred lamb birth weight and weaning weight.

To simulate the effect of selecting Merino ewes for prime lamb production based on their wool ASBVs, the Merino ewes were divided into four flocks based on the SG wool ASBVs (Table 4.3.1) and the reproductive ability of the four flocks was analysed.

Merino ewes from rams with the highest HFD ASBV conceived more lambs (P=0.02) than Merino ewes in the flocks from rams with mid range HFD ASBV (Table 4.3.1). However, there was no difference in conception rate between the three flocks of Merino ewes from rams with HFD ASBV less than zero. There was no effect of splitting Merino ewes into flocks based on their fathers HFD ASBV on the number of Merino ewes that became pregnant, lamb survival or number of lambs weaned or on the reproductive performance of the first cross ewes. There was no difference in reproductive performance between flocks selected on rams HCFW ASBV of the Merino ewes or the first cross ewes.

Table 4.3.1 Actual Merino ewe conception rate, NLW and NLW from their BLxMo first cross ewes lambs grouped into quartiles based on Merino ram hogget fibre diameter (HFD) and hogget clean fleece weight (HCFW) ASBV ranked within year (standard error of the mean in parentheses)

	Ram	HFD ASBV Flock			Ram	ASBV Flock HCFW		
Ram ranking	**ASBV range**	**Conception (%)**	**NLW (%)**	**NLW (%) First cross**	**ASBV range**	**Conception (%)**	**NLW (%)**	**NLW (%) First cross**
4.Highest	-0.8 to 1.5	103 (3.5) [a]	74 (3.7) [a]	79 (6.6)	18.9 to 26.0	95 (3.7)	71 (3.4)	88 (7.0)
3.Mid – high	-1.4 to -0.3	88 (3.3) [b]	75 (3.1) [a]	86 (6.6)	11.9 to 18.4	93 (3.5)	66 (3.2)	74 (5.9)
2.Mid – low	-1.9 to -0.7	97 (3.5) [ab]	65 (2.9) [bc]	75 (6.4)	5.3 to 14.3	95 (3.3)	70 (3.1)	71 (5.6)
1.Lowest	-3.1 to -1.7	95 (3.3) [ab]	68 (3.1) [abc]	72 (6.0)	-5.4 to 6.2	101 (3.9)	74 (3.6)	84 (7.0)

These results suggest that Merino ewes from rams with high HFD ASBVs produced more lambs, but as more pressure is placed on decreasing HFD ASBVs, there was not a similar decline in reproductive rate. Contrary to general belief, based on the rams used in this project, there was no decrease in reproductive rate as HFD ASBVs decreased, thus it is possible to select rams for both decreased fibre diameter without affecting the reproductive performance of their daughters in a prime lamb production system. In addition there was no relationship, either positive or negative, between HCFW ASBVs and reproductive rate. Others have concluded that the weighted mean genetic correlations between fleece weight and the various reproduction traits were small and negative and there were few estimates of correlations of reproduction with fibre diameter or staple length and they were generally low (Safari *et al.* 2005). All of the phenotypic correlations were close to zero, with none reported for staple length.

4.3.2 Merino meat breeding objectives and prime lamb growth

Carcase Plus and Dual Purpose breeding indices were calculated in the Merino database by MGS and SG. Least square mean progeny group liveweights were regressed on the Merino ram Dual Purpose and Carcase Plus breeding indices to determine the relationship between meat orientated breeding objectives and prime lamb growth.

The MGS Carcase Plus Index was correlated with first cross lamb birth weight (r=0.577; P=0.005), weaning weight (r=0.546; P=0.008) and liveweight at approximately 300 days of age (r=0.522; P=0.013). This indicates that using Merino ewes from rams with high MGS Carcase Plus Index will result in increased liveweights of BLxMo lambs. The MGS Carcase Plus Index was also significantly correlated with terminal cross lamb birth weight (r=0.353; P=0.044) but not terminal cross weaning weight or liveweight at 300 days of age (r=0.325; P=0.07). In second cross lambs, MGS Carcase Plus Index of their maternal Merino great grand sires was not correlated with birth weight, weaning weight or liveweight at approximately 300 days of age (r=0.413; P=0.06). Similar relationships occurred with the SG Carcase Plus Index that included all crossbred progeny liveweights in the analysis.

There were no significant correlations between MGS DP8% Index and first cross or second cross lamb live weights. The MGS DP8% Index and weaning weight of terminal cross lambs were significantly correlated (r=0.357; P=0.041). There were no significant correlations between MGS DP8% and birth weight or liveweight at approximately 300 days of age of terminal crossbred lambs (r=0.316; P=0.07).

There was a significant correlation between Merino ram SG DP7% and BLxMo birth weight (r=0.442; P=0.035) but not weaning weight (r=0.397; P=0.06) or liveweight at approximately 300 days (r=0.388; P=0.07). There was no relationship between Merino ram SG DP7% and terminal cross or second cross liveweights.

Merino ram PWWT ASBV was significantly correlated with first cross weaning weight (r=0.575; P=0.004) and liveweight at approximately 300 days of age (r=0.647; P<0.001). Surprisingly there was no significant correlation between Merino ram PWWT ASBV and mean terminal cross or second cross liveweight at approximately 300 days of age.

In summary, there were inconsistent relationships between prime lamb liveweight at approximately 300 days of age and the Carcase Plus and Dual Purpose Indices as well as with PWWT ASBVS of the Merino rams. This suggests that selecting Merino rams using meat orientated indices or PWWT ASBVs will not reliably result in increased liveweight of their terminal cross grand progeny or second cross great grand progeny at slaughter. However there was a significant relationship between liveweight at 300 days of age of the first cross lambs and the MGS Carcase Plus Index as well as with PWWT ASBV. It is possible that the impact of the genes from the Poll Dorset rams is so much greater than that contributed by the Merino, that any effect of the Merino is swamped by the Poll Dorset genes, whereas the BL rams tend to have lower PWWT than the PD, so the BL ram effect is not “swamping” the Merino effect. If this is the case, then it is possible to conclude that the most efficient way of ensuring maximum growth in terminal cross and second growth lambs is to maximise ASBV and Indices in the PD rams rather than focus on the Merino effect.

4.3.3 Reproductive breeding objectives and prime lamb growth

The SG DP3.5% breeding index places high emphasis on reproductive rate and will be used as an example of breeding objective to increase flock reproduction. Least square mean progeny group liveweights were regressed on Merino ram SG DP3.5% breeding index and NLW breeding values to determine the relationship between reproductive orientated breeding objectives and prime lamb growth.

There was no correlation between Merino ram MGS NLW EBV and first cross crossbred lamb liveweights or second cross lamb liveweights. Likewise there was no significant correlation between Merino ram MGS NLW EBV and terminal cross birth weight, weaning weight (r=0.301; P=0.09) or liveweight at 300 days of age (r=0.328; P=0.06). There was a significant correlation between first cross birth weight and Merino ram SG NLW ASBV (r=0.417; P=0.05) but no other significant correlations between Merino ram SG NLW ASBV and crossbred lamb liveweights.

There was a significant correlation between Merino ram SG DP3.5% Index and first cross birth weight (r=0.570; P=0.005), weaning weight (r=0.497; P=0.026) and liveweight at approximately 300 days of age (r=0.491; P=0.017). However, there were no significant correlations between Merino ram SG DP3.5% Index and terminal cross lamb liveweights or second cross lamb birth weight or weaning weight but there was with second cross lamb liveweight at approximately 300 days of age (r=0.413; P=0.05).

These results indicate that there are no negative impacts on crossbred lamb liveweights if emphasis is placed on reproduction in Merino breeding objectives. In fact, adopting breeding objectives for reproductive traits in Merinos may lead to a slight increase in liveweights.

4.3.4 Compatibility between wool, meat and reproductive oriented breeding objectives for Merino sheep

There was no antagonism between prime lamb production and any of the breeding indices or ASBVs that are important in prime lamb production systems that has the Merino ewe as its base. This means that there are no negative impacts on prime lambs produced from Merino ewes that are sourced from ram breeders with wool orientated breeding objectives, with the possible exception of breeding objectives that place very high selection pressure on fibre diameter. In this case, these ewes are likely to wean fewer lambs and the liveweight of these crossbred lambs will be less than lambs from ewes with higher average fibre diameter.

The impact of sourcing ewes based on meat or reproductive ASBVs on number of lambs weaned was examined Section 4.1.2.2. In general, selection of ewes based on liveweight or NLW ASBVs results in an increase in number of lambs weaned, demonstrating the compatibility of between meat and reproductive orientated breeding programs for Merino ewes in prime lamb production systems.

4.4 Improving carcasses and meat quality of crossbred lambs which better fit market requirements

Whether lambs enter the domestic or export trade, lamb markets are generally specified by carcase weight and fat ranges. Key traits affecting market requirements include post weaning weight, fat and eye muscle depth. As well as carcase weight and fat ranges, consumer appeal is also an important factor in keeping consumers satisfied and thus retaining or increasing market share. Finally, consistently meeting market requirements will improve profitability of both the prime lamb producer and the processor.

This section examines some strategies that can be used by prime lamb producers to improve carcasses and meat quality of first cross and terminal cross lambs which better fit market requirements.

4.4.1 Predicting carcase measurements from live animal measurements

Being able to predict carcase measurements will enable prime lamb producers and processors to place the lambs in the most suitable market prior to slaughter, thus streamlining processing pathways. This section examines whether crossbred lamb fatness measured in the live lamb using fat scoring and ultrasound scanning or calculated with ASBVs can be used as an indicator of carcase traits. The relationships between live animal measures and other carcase traits in terminal crossbred lambs are also described. Previous reports have found low correlations between live animal and carcase fat measures in second cross lambs (Hall *et al.* 2001)

4.4.1.1 Relationship between live animal measures and carcase measurements

Individual carcase measurements were regressed on individual live animal measurements to determine the relationship between live animal measurements and carcase measurement in crossbred lambs (Table 4.4.1). The majority of correlations were in agreement with that reported in published literature (Hopkins *et al.* 2008). In general as liveweight increases there was an increase in carcase weight, cEMD, cEMW, cfat and GR. There were inconsistent correlations between liveweight and objective measurement of eating quality. In first cross lambs, as liveweight increased, loins became lighter in colour and slightly tougher. In terminal cross and second cross lambs, as liveweight increased, loins became darker and redder; glycogen content of the muscle increased, pH decreased and the loins were more tender.

Table 4.4.1 Relationship between liveweight and FWEC with carcase traits in three types of crossbred lambs (CCWT = cold carcase weight; GR = GR thickness; EMD = eye muscle depth; cfat = cfat thickness; colour = loin colour lightness/redness; pH = pH of the loin 24h after slaughter; SF = shear force of the loin; glycogen = glycogen potential of the loin)

	BLxMo		PDxMo		PDxBLxMo	
	Liveweight	**FWEC**	**Liveweight**	**FWEC**	**Liveweight**	**FWEC**
CCWT	+++	ns	+++	- - -	+++	- - -
GR	+++	ns	+++	- - -	+++	- - -
EMD	+++	ns	+++	- - -	+++	- - -
Cfat	+++	ns	+++	-	+++	ns
Colour	- -	ns	- - - / +++	- -	++	- - -
pH	ns	ns	- - -	+++	- - -	+++
SF	+	ns	- - -	+	- -	ns
glycogen	ns	ns	+	+	-	ns

+++/--- = positive/negative correlation (P<0.0001); ++/-- = positive/negative correlation (P<0.001); +/- = positive/negative correlation (P<0.01); ns = no significant correlation

These results indicate that the relationships between live animal measurements and carcase measurements in crossbred lambs are generally consistent, regardless of cross type. Therefore, live animal measurements can be used as general predictors of carcase characteristics for all types of crossbred lambs.

Interestingly increased FWEC was significantly correlated with lower carcase weights, GR thickness and EMD in terminal cross and second cross lambs. Furthermore, increased FWEC was associated with increased loin pH. This is surprising that a relationship was detected as FWEC was measured not long after weaning, at least 5 to 7 months prior to slaughter. It is possible that crossbred lambs that have lower FWEC may be "fitter" and therefore less prone to other diseases thus resulting in larger carcasses. Negative phenotypic and genetic correlations between FWEC and growth traits have been reported in Welsh Mountain sheep, (Ap Dewi *et al.* 2002), further supporting the beneficial relationship between lamb health and growth.

4.4.1.2 Relationship between crossbred lamb fat and EMD ASBVs, ultrasound carcase measurements and actual carcase measurements

Terminal sires selected on the basis of their LAMBPLAN estimated breeding values produced crossbred lambs that reflect their breeding values for carcase traits (Fogarty *et al.* 1997; Hall *et al.* 2002; Hall *et al.* 1995; Hegarty *et al.* 2006b).

Individual carcase measurements were regressed on individual live ultrasound measurements of EMD and fat depth, EMD and fat ASBVs and on manual fat score to determine the relationship between live animal measurements and carcase measurement in crossbred lambs.

There were highly significant relationships between actual carcase measurements and the live animal measurements in the terminal cross lambs (Table 4.4.2). All cross types had significant relationships between carcase measurements and the ultrasound and manual measurement of fat and EMD.

However, the correlations between ASBVs and carcase measurements were low in the first cross and second cross lambs. In particular there was a poor relationship between EMD in the carcase and EMD ASBV in the first cross and second cross lambs. This is of concern as the EMD ASBVs are for individual lambs and live animal data would have been used to calculate the EMD ASBVs as it would be expected that there would be a good relationship.

These results indicate that live animal measurements are good indicators of carcase EMD, cfat thickness and GR, however ASBVs of the individual lambs are not reliable indicators of carcase measurements, particularly for the first cross and second cross lambs. The live animal measurements measure the phenotype of the lamb whereas the ASBV is a measurement of the genotype. As the market is interested in the phenotype, actual measurements are better predictors of carcase attributes than ASBVs.

Table 4.4.2 Relationship between actual carcase measurements of EMD, cfat and GR thickness and crossbred lamb fat and EMD ASBVs, ultrasound measurement of EMD (EMD scan) and fat depth (cfat scan) and fat score (Pearson correlation coefficients)

BLxMo	EMD scan	EMD ASBV	Fat score	Cfat scan	FAT ASBV
EMD carcase	**0.339 (P<0.0001)**	**0.012 (ns)**	0.054 (ns)	0.185 (P=0.009)	-0.020 (ns)
Cfat carcase	0.204 (P=0.003)	0.328 (P<0.0001)	**0.438 (P<0.0001)**	**0.460 (P<0.0001)**	**0.340 (P<0.0001)**
GR carcase	0.103 (ns)	0.591 (P<0.0001)	0.555 (P<0.0001)	0.397 (P<0.0001)	0.533 (P<0.0001)

Table 4.4.3 cont. Relationship between actual carcase measurements of EMD, cfat and GR thickness and crossbred lamb fat and EMD ASBVs, ultrasound measurement of EMD (EMD scan) and fat depth (cfat scan) and fat score (Pearson correlation coefficients)

PDxMo	EMD scan	EMD ASBV	Fat score	Cfat scan	FAT ASBV
EMD carcase	**0.649 (P<0.0001)**	**0.298 (P<0.0001)**	0.527 (P<0.0001)	0.585 (P<0.0001)	0.272 (P<0.0001)
Cfat carcase	0.363 (P<0.0001)	0.198 (P<0.0001)	**0.409 (P<0.0001)**	**0.423 (P<0.0001)**	**0.255 (P<0.0001)**
GR carcase	0.665 (P<0.0001)	0.280 (P<0.0001)	0.688 (P<0.0001)	0.680 (P<0.0001)	0.284 (P<0.0001)
PDxBLxMo					
EMD carcase	**0.700 (P<0.0001)**	**0.155 (P=0.03)**	0.524 (P<0.0001)	0.616 (P<0.0001)	0.049 (ns)
Cfat carcase	0.247 (P<0.0001)	0.247 (P<0.001)	**0.321 (P<0.0001)**	**0.373 (P<0.0001)**	**0.344 (P<0.0001)**
GR carcase	0.771 (P<0.0001)	0.156 (P=0.03)	0.717 (P<0.0001)	0.714 (P<0.0001)	0.099 (ns)

4.4.2 Relationship between Merino ram ASBVs, common Merino Breeding Indices and meat production

Merinos tend to produce meat that is darker with a higher pH than other breeds of sheep (Hopkins and Fogarty, 1998) and it is believed that the greater the proportion of Merino genes in a lamb the less enjoyable the eating experience. Recent studies on eating quality do not support this perception and indicate that careful management of pre-slaughter conditions such as growth rate and low stress may remove differences in eating quality (Hopkins et al 2005). Nevertheless, there is opportunity to identify first and terminal cross prime lambs that are more likely to consistently produce a product that meets market requirements despite pre-slaughter conditions.

Variation between Merino rams exists in the objective measurements of eating quality (Section 4.2.2). As well as potentially impacting on prime lamb production (Section 4.3), Merino breeding objectives may affect the carcase and meat traits of crossbred lambs. This section examines the relationship between Merino ram ASBVs, common Merino Breeding Indices and meat production and its potential impact on meeting market requirements.

Progeny group least square means of carcase characteristics of terminal crossbred lambs estimated in section 4.2 were compared to the Merino EBVs calculated by MGS in October 2005 and Merino ram ASBVs calculated in the Merino SG database in July 2007.

There were no significant correlations between terminal crossbred lamb carcase characteristics and Merino ram ASBVs for PWWT, FAT, EMD, HCFW, HFD, AFD and NLW (Appendix 5). This is surprising as it has been shown that there is significant positive relationship between Poll Dorset Fat EBV and the c-fat thickness of their crossbred lambs carcase (Hegarty *et al.* 2006b) and Poll Dorset EMD EBV and carcase EMD of their crossbred progeny (Hegarty *et al.* 2006a).

There was a significant negative correlation between loin shear force and ACFW ASBV (r=-0.359; P=0.037; Figure 4.), suggesting that Merino rams with high ACFW ASBVs will produce terminal cross grand lambs with tender loins. One of the Merino rams is a Dohne and he has an outlier ACFW. If this data point is removed there is a very strong negative correlation between ACFW ASBV and loin tenderness. There was also a significant correlation between the Merino ram MGS NLW EBV and carcase weight of the terminal crossbred lambs (r=0.38; P=0.03).

The weighted mean genetic correlations for wool weight (clean and greasy) with fat depth (−0.19) and muscle depth (0.23) measured in both live animals and carcasses were moderate and varied in sign, while those for fibre diameter were 0.18 and 0.07 respectively (Safari *et al.* 2005)

There were no correlations between the MGS or SG Merino ram Indices and terminal cross lamb carcase characteristic or eating quality. This indicates that producing terminal crossbred lambs from ewes bred from Merino rams selected on any of the common Merino Breeding Indices will not have an impact on carcase traits either positively or negatively.

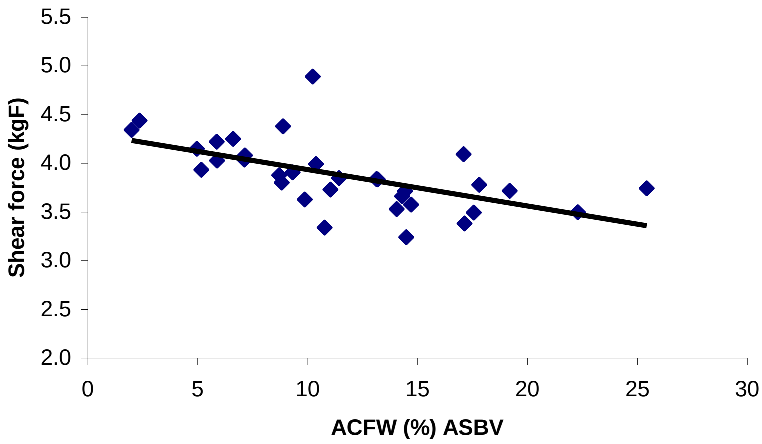


Figure 4 Relationship between Merino ram ACFW ASBV and the average shear force of terminal crossbred lamb progeny groups

4.4.3 Relationship between lamb temperament and meat production

The following section was presented at the ASAP Conference in Perth 2006 (Starbuck *et al.* 2006).

Temperament scoring and flight speed have been used in cattle as a predictor of growth (Graham *et al.* 2001) and meat quality (Voisinet *et al.* 1997) and it is possible that similar relationships may exist for sheep. Several tests utilising specialist equipment (flight speed recorder, jiggle box) or situations (Murphy 1999) have been developed to assess temperament or fearfulness in sheep but from a commercial perspective it would be desirable to develop a measure that can be recorded during routine management activities and that does not use specialist equipment. The aim of this study was to evaluate an objective measurement, recorded during routine management of prime lambs that maybe a repeatable measure of temperament/fearfulness in lambs.

Poll Dorset x Merino first cross lambs (n=224; aged between 214-258 days) and Poll Dorset x Border Leicester x Merino second cross lambs (n=66; 158-194) born in 2004 as part of larger experiment were weighed in a weigh crate with solid sides and a partially enclosed top and outward opening door (0.8m high x 1.12m long, & 0.4mwide at top, 0.28m wide at base). Whilst being weighed, the time taken for the animal to become stationary was recorded with a hand held stop watch (Settling Time); stationary was defined as feet not moving and no significant movement of the head or body for a period of 5 seconds. A cut-off point of 120secs was used as the upper limit and non-stationary sheep were released at that time. This procedure was repeated on the following day, although liveweights were not recorded on the second occasion. The effect of day and lamb breed cross on settling time was analysed by Proc Mixed (SAS v8.0).

Settling time data were log transformed for analysis and results presented are back transformed least square means. A Pearson correlation coefficient was used to assess the repeatability of settling time for individual lambs on the two days.

First cross lambs settled significantly faster than the second cross lambs (P<0.0001) and both breed crosses settled faster on the second day of assessment compared to the first day of measurement (P< 0.0001; Table 4.4.3). There was also a significant correlation between settling time measured on sequential days (r=0.394; P<0.0001), however Figure 5 shows that there was wide variation around the line of best fit.

Table 4.4.4 Settling time (second) of first and second cross lambs measured on 2 consecutive days (Day no.)

	Settling time		
Day no.	1	2	SE
First Cross	22.9	17.1	1.04
Second Cross	31.3	23.8	1.09

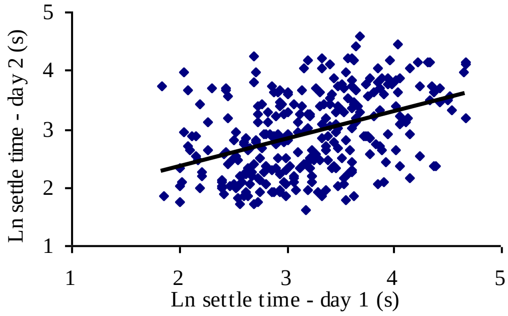


Figure 5. Relationship between settling time of first and second cross lambs measured on 2 consecutive days (day 1 and day 2.)

Settling time does vary widely between individual lambs and with breed crosses suggesting that it is worthy of closer scrutiny as an indicator of fearfulness. However the current study also indicates that it may not be a suitable measurement for selection as there was considerable variation in individual animal times across days. As there was a significant decline in mean settling time between day 1 and day 2, it maybe that the poor repeatability was due to differences in habituation to handling and the test should be re-evaluated in animals handled a number of times before testing or alternatively with a number of days between tests. Therefore further analysis is required to determine whether settling time is a useful measure of fearfulness/temperament and also if it is related to other production traits.

4.4.4 Conclusion - Improving carcasses and meat quality of crossbred lambs which better fit market requirements

This section examined some strategies that can be used by prime lamb producers to improve carcasses and meat quality of first cross and terminal cross lambs which better fit market requirements. Carcase and meat quality of crossbred lambs can be improved to better fit market requirements by:

- Using live animal measurements such as liveweight, ultrasound scanning and fat scoring as indictors of carcase attributes rather than ASBVs.
- Using Merino ewes whose fathers have similar ASBVs as there is considerable variation between the crossbred progeny of Merino rams in carcase traits. Decreasing the genetic variation in the Merino ewe flock is likely to result in a more even and consistent line of crossbred lambs.
- Using Merino ewes that have fathers with superior EMD ASBVs as there was significant variation in carcase EMD between crossbred progeny from different Merino rams (Section 4.2.2.1 & 4.2.2.3).
- Using older ewes to produce crossbred lambs, as lambs born to ewes from their first mating to Poll Dorset rams were lighter, had smaller EMD, lower c-fat thickness and higher FWEC than lambs born to ewes at their second mating to Poll Dorset rams (Section 4.1.2.6).

Encouragingly, there were no unfavourable correlations between crossbred lamb liveweight and carcase traits or objective measurements on eating quality. This means that if liveweights are increased to meet market requirements there is unlikely to be any negative effects on eating quality. In fact, as cold carcase weight increased there was a decrease in pH 24h after slaughter (Section 4.2.2.4).

Merino breeding objectives are unlikely to have any negative impacts on meeting market requirements but conversely they are unlikely to assist in meeting market requirements. One aspect which may need further research is the negative relationship between Merino ram ACFW ASBV and loin shear force of their terminal crossbred grand progeny.

Finally the impact of temperament on carcase traits is still not well understood. There are suggestions that temperament may impact of prime lamb production. This may be a strategy that can be used to decrease the impact of pre-slaughter stress on eating quality.

5 Success in achieving objectives

5.1 Improved lamb production through greater awareness of the influence of Merino genes on prime lamb production in commercial enterprises

Merino ram had a significant effect on the liveweight ASBVs of first, terminal and second cross lambs. Thus, to optimise first and terminal cross prime lamb production systems it is important to source Merino ewes whose fathers have high genetic potential for liveweight in order to maximise the liveweight of the prime lambs. Merino ram had an effect on PEMD, PFAT and WWEC ASBVs for all three crossbred lamb types indicating that there is significant variation between Merino rams in these traits, however, this was only expressed phenotypically in the terminal cross lambs.

Prime lamb production can be improved by;

- Mating Merino ewes whose fathers have high NLW ASBVs. This will result in increasing the genetic potential of number of lambs weaned through improved conception rates. This is particularly important for the production of first cross ewes that will be mated to produce second cross lambs.
- Mating heavy hogget Merino ewes to increase the number of lambs weaned.
- Mating older Merino ewes to increase the number of lambs weaned. Older Merino ewes had higher number of lambs weaned due to fewer dry ewes and increased conception rates.
- Mating Merino ewes whose fathers have high PWWT ASBVs to increase post weaning liveweight of the first and terminal crossbred lambs. In this project, there was a 6kg difference at approximately 300 days of age in terminal cross between grand progeny of different merino rams.
- Mating Merino ewes whose fathers have high ASBV for fat and EMD in terminal cross lambs.
- Mating Merino ewes whose fathers have similar ASBVs to create more consistent lines of prime lambs.

The Merino ram had less of an effect on second cross lambs production.

5.2 Greater accuracy in genetic evaluation of meat related traits due to improved estimates of phenotypic and genetic parameters

All phenotypic measures of carcase traits, including hot and cold carcase weights, GR depth, loin eye muscle depth, width and fat thickness, loin pH, loin colour, glycogen potential and loin tenderness have been submitted to Sheep Genetics for inclusion in the database. These measurements can therefore be used to increase the accuracy in genetic evaluation of meat related traits by improving the estimates of genetic parameters. Phenotypic effects of Merino rams on carcase traits and objective measurement of eating quality were analysed and reported.

This project has provided a comprehensive set of measurements including hard to measure traits such as eating quality and reproductive ability as well as linkage between several Merino genetic databases.

This project has provided a comprehensive dataset of both standard and hard to measure traits such as eating quality and reproductive ability to MLA. The Merino rams used in this project also provided linkage between several Merino databases. This information has been used to assist in the development of a single Merino database to provide breeding values for Merino producers.

5.3 Compatibility between wool, meat and reproductive oriented breeding objectives for Merino sheep

There was no antagonism between prime lamb production and any of the breeding indices or ASBVs that are important in prime lamb production systems that has the Merino ewe as its base. This means that there are no negative impacts on prime lambs produced from Merino ewes that are sourced from ram breeders with wool orientated breeding objectives. Unexpectedly, there was no benefit for prime lamb production in producing crossbred lambs from rams with superior meat orientated breeding programs. However, sourcing ewes based on liveweight or NLW ASBVs results in an increase in number of lambs weaned, demonstrating the compatibility of between meat and reproductive orientated breeding programs for Merino ewes in prime lamb production systems.

5.4 Improving carcasses and meat quality of first cross lambs which better fit market requirements

Carcase and meat quality of crossbred lambs can be improved to better fit market requirements by:

- Using live animal measurements such as liveweight, ultrasound scanning and fat scoring as indictors of carcase attributes rather than ASBVs.
- Using Merino ewes whose fathers have similar ASBVs as there is considerable variation between the crossbred progeny of Merino rams in carcase traits. Decreasing the genetic variation in the Merino ewe flock is likely to result in a more even and consistent line of crossbred lambs.
- Using Merino ewes that have fathers with superior EMD ASBVs as there was significant variation in carcase EMD between crossbred progeny from different Merino rams (Section 4.1.3).
- Using older ewes to produce crossbred lambs, as lambs born to ewes from their first mating to Poll Dorset rams were lighter, had smaller EMD, lower c-fat thickness and higher FWEC than lambs born to ewes at their second mating to Poll Dorset rams (Section 4.1.3).

6 Impact on meat and livestock industry – Now and in five years time

This project was established as part of a national MLA-supported program evaluating Merino genetics in the prime lamb industry. The data collected in this project has provided a comprehensive set of measurements of standard and hard to measure traits such as eating quality and reproductive ability. The Merino rams used in this project also provides linkage between the various databases. This information has already had an impact on the meat and livestock industry through the development of a single Merino database to provide breeding values for Merino producers.

Merino genes are important in the prime lamb industry. Results from this project will have an immediate impact in the prime lamb industry by demonstrating that Merino genes do influence the number of lambs produced, carcase weight and some aspects of meat quality. Prime lamb producers should be encouraged to select Merinos that have high growth potential and carcase traits as this will be expressed in their prime lambs.

Prime lamb producers, particularly producers of terminal crossbred lambs will benefit from these results by understanding the impact the Merino ewe in their prime lamb productions system will have on their profit drivers. The Merino ewe affects both the number of lambs weaned and their slaughter weight.

Processors can benefit from these results through producers supplying lambs that better fit into the abattoirs requirements. Consistently meeting market requirements will improve profitability of both the prime lamb producer and the processor. There was considerable variation between prime lamb progeny groups and this will have an impact on achieving an even and consistent line of prime lambs. Prime lamb producers that wish to achieve an even line of lambs, generally select rams with similar ASBVs. If attention is paid to sourcing Merino ewes which have similar liveweight, fat and EMD ASBVs there will be less variation in their lambs.

7 Conclusions and recommendations

Merino genes affect prime lamb production by impacting on some of the profit drivers of the prime lamb business. Merino ram influences the number of lambs weaned from his daughters and liveweight, carcase traits and eating quality of terminal cross lambs. However, the ability to identify or select rams with favourable traits for prime lamb enterprises is difficult as in this trial Merino ram ASBVS and selection indices were not a good indicator of phenotypic measures of reproduction, liveweight or carcase traits. In fact, the best predictor for identifying ewes for prime lamb production systems, at least in terms of number of lambs weaned, was using ewes with the highest liveweight at hogget mating, or using older ewes.

Factors that affect reproductive rate in Merino ewes are complex. A more detailed understanding of the relationship between liveweight, CS, genetics and reproduction is needed to enable prime lamb producer to identify and optimising the Merino ewe that is most suited to their enterprise. Current recommendations that fat score or CS of 3 is ideal, but this does vary between Merino rams. It may be possible to achieve 100% NLW or greater from some genotypes that have lower condition or fat scores.

Finally the impact of temperament on carcase traits is still not well understood. There are suggestions that temperament may impact of prime lamb production and this may be a strategy that can be used to decrease the impact of pre-slaughter stresses on eating quality. It was anticipated that a Masters student would measure the impact of crossbred lamb temperament on prime lamb production. The data was collected, however the Masters student that was undertaking the work transferred from a project based Masters to a coursework based Masters and the analysis of the results has not been completed.

8 Bibliography

Afolayan RA, Fogarty NM, Ingham VM, Gilmour AR, Gaunt GM, Cummins LJ, Pollard T (2007) Genetic evaluation of crossbred lamb production. 3. Growth and carcass performance of second-cross lambs. *Australian Journal of Agricultural Research* **58**, 457-466.

Ap Dewi I, Saachi M, Ulutas Z (2002) Genetic parameters of weights, ultrasonic muscle and fat depths, maternal effects and reproductive traits in Welsh Mountain sheep. *Anim. Sci.* **74**, 399-408.

Banks RG (2002) An integrated system of genetic evaluation and improvement tools for Australian sheep breeders. *Wool Technology and Sheep Breeding* **50**, 359-365.

Edey TN (1968) Bodyweight and ovulation rate in sheep. *Proc. Aust. Soc. Anim. Prod.* **7**, 188-191.

Fogarty NM (1995) Genetic parameters for live weight, fat and muscle measurements, wool production and reproduction in sheep: a review. *Anim. Breed. Abstr.* **63**, 101-143.

Fogarty NM, Gilmour AR, Hopkins DL (1997) The relationship of crossbred lamb growth and carcass traits with LAMBPLAN EBVs of sires. *Association for the Advancement of Animal Breeding and Genetics.* **12**, 304-308.

Fogarty NM, Ingham V, McLeod L, Morgan JE, Gaunt G (2005a) More $$$s from crossbred ewes with the right genetics. NSW Department of Primary Industries, Technical Bulletin No., Orange.

Fogarty NM, Ingham VM, Gilmour AR, Cummins LJ, Gaunt GM, Stafford J, Edwards JEH, Banks R (2005b) Genetic evaluation of crossbred lamb production. 2. Breed and fixed effects for post-weaning growth, carcass, and wool of first-cross lambs. *Australian Journal of Agricultural Research* **56**, 455-463.

Fogarty NM, Safari E, Taylor PJ, Murray W (2003) Genetic parameters for meat quality and carcass traits and their correlation with wool traits in Australian Merino sheep *Australian Journal of Agricultural Research* **54**, 715-722.

Gardner GE, Kennedy L, Milton JTB, Pethick DW (1999) Glycogen metabolism and ultimate pH of muscle in merino, first cross and second cross wether lambs as affected by stress before slaughter. *Australian Journal of Agricultural Research* **50**, 175-181.

Graham JF, Clark AJ, Thomsom K, Kearny G (2001) *Proc. Assoc.Advmt.Anim.Breed.Genet* **14**, 75.

Hall DG, Gilmour AR, Fogarty NM, Holst PJ (2002) Growth and carcass composition of second-cross lambs. 2. Relationship between estimated breeding values of sires and their progeny performance under fast and slow growth regimes. **53**, 1341-1348.

Hall DG, Gilmour AR, Fogarty NM, Holst PJ, Hopkins DL (2001) Growth and carcass composition of second-cross lambs. 1. Effect of sex and growth path on pre- and post-slaughter estimates of carcass composition. **52**, 859-867.

Hall DG, Luff AF, Fogarty NM, Holst PJ (1995) LAMBPLAN and weight and fat responses in second cross lambs. *Association for the Advancement of Animal Breeding and Genetics.* **11**, 185-189.

Harris PV, Shorthose WR (1988) Meat Texture. In 'Developments in Meat Science'. (Ed. R Lawrie) pp. 245-296. (Elsevier Applied Science: London).

Hegarty RS, Hopkins DL, Farrell TC, Banks R, Harden S (2006a) Effects of available nutrition and sire breeding values for growth and muscling on the development of crossbred lambs. 2: Composition and commercial yield. *Australian Journal of Agricultural Research* **57**, 617-626.

Hegarty RS, Shands C, Marchant R, Hopkins DL, Ball AJ, Harden S (2006b) Effects of available nutrition and sire breeding values for growth and muscling on the development of crossbred lambs. 1: Growth and carcass characteristics. *Australian Journal of Agricultural Research* **57**, 593-603.

Hocking Edwards JE, Edwards NJ, Starbuck TJ, Ball AJ, van der Werf JHJ (2004) Terminal sire influences lamb meat quality. In '25th Biennial Conference of the Australian Society of Animal Production'. Melbourne, WA. (Ed. R Stockdale, Heard, J., Jenkin, M.).

Hopkins DL, Hegarty RS, Farrell TC (2005a) Relationship between sire estimated breeding values and the meat and eating quality of meat from their progeny grown on two planes of nutrition. *Australia Journal of Experimental Agriculture* **45**, 525-533.

Hopkins DL, Ponnampalam EN, Warner RD (2008) Predicting the composition of lamb carcases using alternative fat and muscle depth measures *Meat Science* **78**, 400-405.

Hopkins DL, Walker PJ, Thompson JM, Pethick DW (2005b) Effect of sheep type on meat and eating quality of sheep meat. *Australia Journal of Experimental Agriculture* **45**, 499-507.

Huisman AE, Brown DJ (2008) Genetic parameters for bodyweight, wool, and disease resistance and reproduction traits in Merino sheep. 2. Genetic relationships between bodyweight traits and other traits pp. 1186-1193.

Martin P (2004) Prime lamb industry- production & sale of sheep & lambs. ABARELamb 04.3.

Michels H, Decuypere E, Onagbesan O (2000) Litter size, ovulation rate and prenatal survival in relation to ewe body weight: genetics review. *Small Ruminant Research* **38**, 199-209.

Murphy PM (1999) PhD Thesis. The University of Western Australia.

Safari E, Fogarty NM, Gilmour AR (2005) A review of genetic parameter estimates for wool, growth, meat and reproduction traits in sheep. *Livestock Production Science* **92**, 271-289.

Safari E, Fogarty NM, Gilmour AR, Atkins KD, Mortimer SI, Swan AA, Brien FD, Greeff JC, van der Werf JHJ (2007) Across population genetic parameters for wool, growth, and reproduction traits in Australian Merino sheep. 2. Estimates of heritability and variance components. *Australian Journal of Agricultural Research* **58**, 177-184.

SAS (2002-2003) SAS Institute Inc.Cary, NC, USA.).

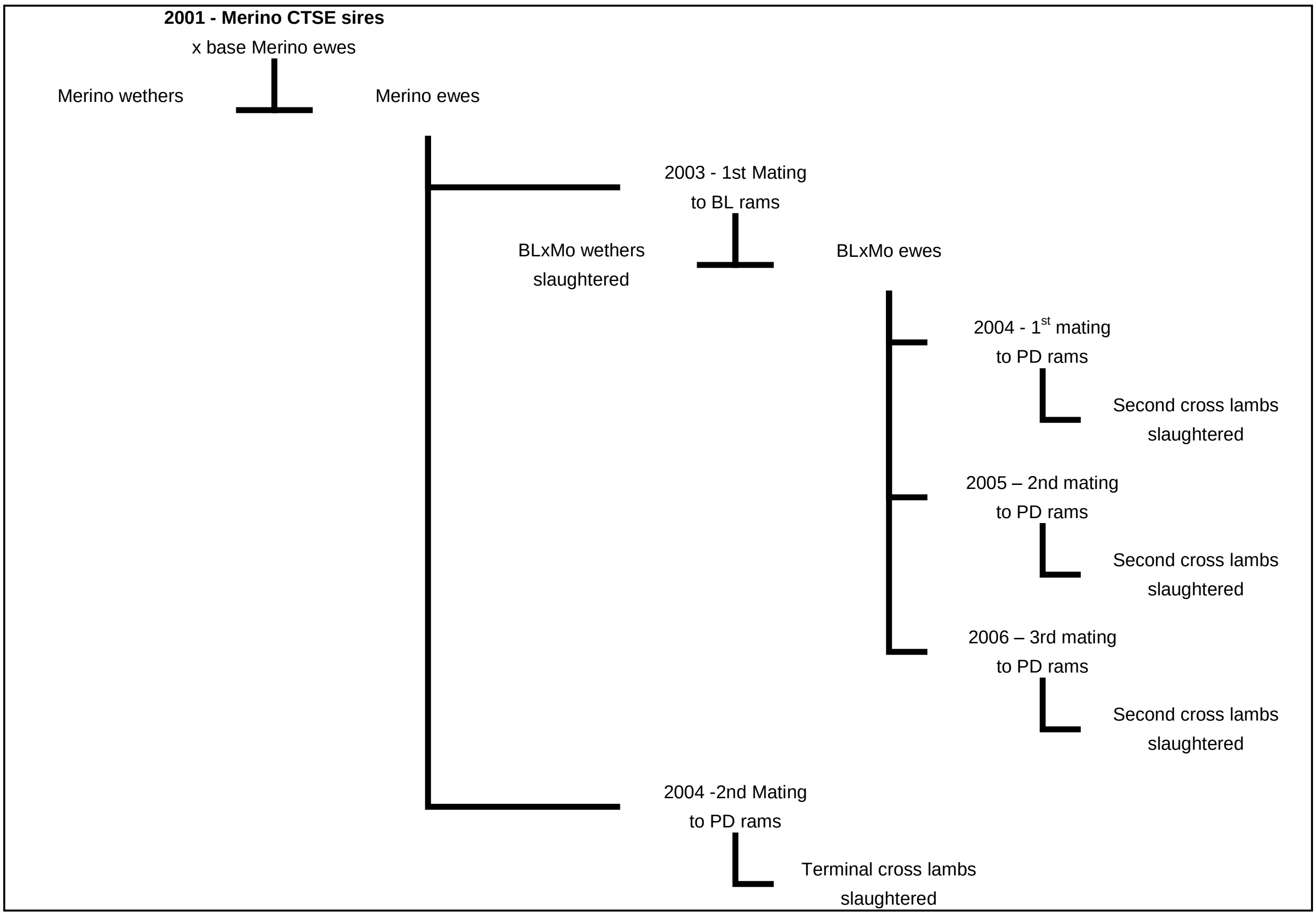
Starbuck T, Hocking Edwards J, Hinch G (2006) Measurement of temperament/fearfulness of lambs without the use of specialist equipment. . In '26th Biennial Conference of the Australian Society of Animal Production'. Perth, WA. (Ed. KA Croker, N; Lindsay, D).

Voisinet BD, Grandin T, O'Connor SF, Tatum JD, Deesing MJ (1997) *Meat Science* **46**.

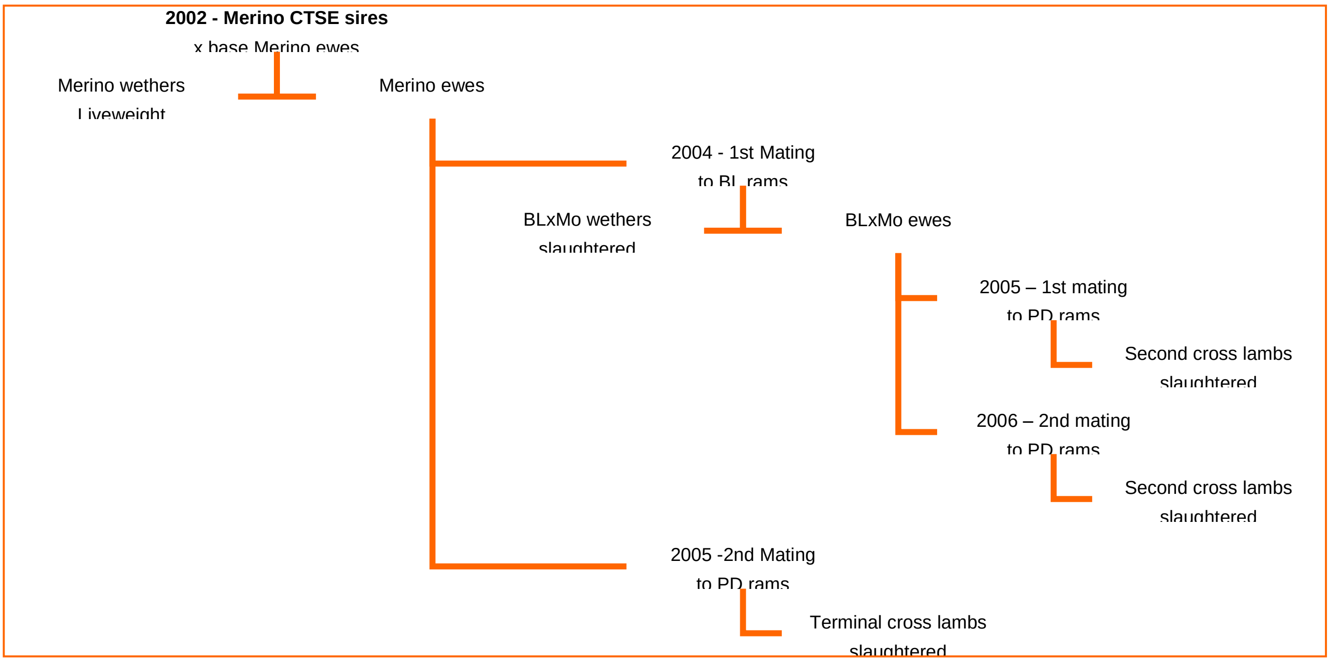
9 Appendices

9.1 Appendix 1: Experimental design

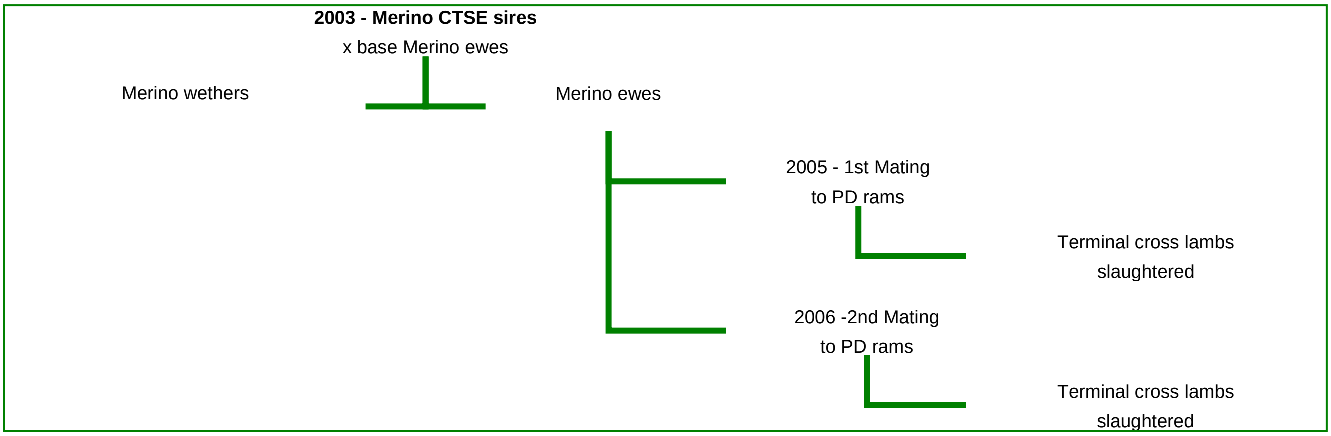
9.1.1 (a) Production and mating of the 2001 drop Merino ewes



9.1.2 (b) Production and mating of the 2002 drop Merino ewes



9.1.3 (c) Production and mating of the 2003 drop merino ewes



9.2 Appendix 2: Merino ram ASBVs (accuracy), number of progeny (Prog) and number of flocks (Flock) calculated by SG in July 2007

.

Registered id	BWT (kg)	WWT (kg)	PWWT (kg)	NLW (kg)	Prog	Flock
5001531995000013	0.502 (73)	3.556 (94)	7.55 (87)	0.067 (66)	132	2
5003831997006460	0.038 (79)	-0.434 (94)	-2.192 (91)	-0.056 (69)	725	2
5003831997006561	-0.038 (94)	1.357 (97)	0.511 (94)	0.102 (66)	1661	11
5007881998980824	0.824 (78)	2.107 (94)	0.813 (90)	-0.071 (67)	310	3
5027242000000161	0.888 (93)	2.569 (81)	4.299 (85)	0.106 (68)	121	1
5034711998980053	0.168 (95)	1.65 (95)	-2.665 (97)	0.054 (82)	444	2
5043381996961115	-0.28 (80)	0.252 (95)	-2.042 (93)	-0.028 (77)	277	4
5046152001013137	0.146 (95)	3.543 (94)	3.015 (95)	-0.016 (78)	242	2
5046451998008051	-0.072 (81)	3.223 (96)	1.253 (93)	-0.06 (66)	394	5
5046451998008548	-0.01 (93)	1.09 (86)	-0.76 (89)	0.007 (67)	156	2
5046451999009036	-0.548 (82)	-0.036 (94)	-2.642 (91)	0.117 (71)	231	2
5046481999990431	0.16 (75)	3.221 (94)	5.873 (89)	-0.01 (65)	85	2
5046482000001439	-0.153 (74)	0.795 (92)	-2.003 (87)	0.055 (67)	60	1
5046521999990382	-0.107 (80)	0.294 (97)	-2.93 (92)	0.263 (65)	195	2
50901000000000X1	0.13 (81)	0.412 (94)	-1.385 (91)	-0.145 (71)	193	2
50901000000000X2	0.167 (67)	0.433 (91)	3 (84)	-0.091 (60)	50	1
50901000000000X3	0.577 (74)	1.729 (96)	-0.264 (90)	-0.08 (62)	148	2
509116199700SDF1	-0.095 (76)	2.385 (94)	4.37 (88)	0.116 (67)	78	1
509116199700SDF2	0.037 (79)	1.582 (95)	-1.274 (90)	-0.08 (75)	126	1
509116199800SDF3	0.601 (79)	4.533 (95)	7.106 (89)	0.134 (73)	117	1
509116199800SDF4	0.014 (70)	0.419 (90)	-2.724 (85)	0.045 (61)	43	1
5100061999990011	0.381 (89)	6.354 (95)	13.166 (93)	0.505 (75)	93	2
6000881997000H39	0.133 (82)	2.832 (96)	3.081 (96)	0.093 (69)	202	6
6000882000H39050	0.053 (72)	1.593 (92)	0.436 (86)	0.056 (63)	51	1
600408199700RED1	-0.146 (77)	1.121 (96)	1.544 (96)	0.075 (65)	195	3
6005711997970248	0.01 (95)	1.195 (95)	-0.937 (94)	0.104 (87)	591	5
60103220010Y1042	-0.105 (91)	-0.538 (81)	-0.757 (84)	0.023 (67)	74	1
6010532001011075	0.262 (93)	2.793 (97)	1.883 (97)	-0.046 (77)	367	2
6010532001011101	0.136 (93)	0.432 (94)	-2.536 (96)	-0.093 (75)	200	2
601082199595B320	0.31 (93)	1.734 (95)	2.397 (95)	-0.008 (71)	277	3
6010881997002897	0.698 (94)	4.454 (97)	3.837 (95)	-0.057 (75)	463	6
601226199800MZ16	0.815 (63)	5.622 (87)	5.451 (81)	0.028 (56)	27	1
6012501999907244	0.194 (97)	4.293 (98)	5.317 (98)	0.075 (88)	1081	19
6012911998980353	0.205 (96)	5.503 (98)	7.083 (98)	0.107 (90)	718	7

9.3 Appendix 3. Year of artificial insemination and total number Merino and first cross ewes from each Merino ram

Merino Ram	Year	Merino ewes	First cross ewes	Merino Ram	Year	Merino ewes	First cross ewes
5001531995000013	2001	34	13	502251199800G100	2002	24	8
5007881998980824	2001	32	8	509116199800SDF4	2002	21	15
5100061999990011	2001	41	22	6000881997000H39	2002	13	6
5046451996096035	2001	34	12	60008820000H3950	2002	19	9
503762199900W969	2001	23	5	601226199800MZ16	2002	17	5
509116199700SDF1	2001	33	13	*6012911998980353*	*2002/03*	*85*	*11*
509116199700SDF2	*2001/02*	*60*	*18*	5003831997006561	2003	27	-
509116199800SDF3	*2001/02*	*48*	*14*	6007942000000161	2003	41	-
600408199700RED1	2001	30	10	5034711998980053	2003	58	-
6010881997002897	*2001/03*	*54*	*8*	5046152001013137	2003	55	-
5003831997006460	2002	33	14	5046451998008548	2003	35	-
5043381996001115	2002	17	6	6005711997970248	2003	59	-
5046451998008051	2002	21	7	6010532001011075	2003	28	-
5046451999009036	2002	29	8	6010532001011101	2003	40	-
5046481999999431	2002	25	3	6012501999907244	2003	47	-
5046482000000439	2002	33	12	60103220010Y1042	2003	37	-
5046521999990382	2002	24	14	601082199595B320	2003	28	-

Link sires are italicised.

9.4 Appendix 4. Year of artificial insemination and total number of carcasses from each Merino ram

Merino Ram	Year	Maternal	Terminal	Second	Merino Ram	Year	Maternal	Terminal	Second
5001531995000013	2001	7	17	31	50901000000000X3	2002	9	16	6
5007881998980824	2001	11	23	22	509116199800SDF4	2002	5	19	11
5100061999990011	2001	20	47	68	6000881997000H39	2002	2	10	5
50901000000000X1	2001	11	17	27	6000882000H39050	2002	5	16	9
50901000000000X2	2001	8	13	9	601226199800MZ16	2002	3	12	5
509116199700SDF1	2001	8	29	35	*6012911998980353*	*2002/03*	*12*	*105*	*14*
509116199700SDF2	*2001/02*	*13*	*40*	*33*	5003831997006561	2003	-	31	-
509116199800SDF3	*2001/02*	*18*	*42*	*19*	5027242000000161	2003	-	41	-
600408199700RED1	2001	3	19	22	5034711998980053	2003	-	63	-
6010881997002897	*2001/03*	*7*	*54*	*20*	5046152001013137	2003	-	48	-
5003831997006460	2002	11	24	11	5046451998008548	2003	-	45	-
5043381996961115	2002	3	12	6	6005711997970248	2003	-	63	-
5046451998008051	2002	6	13	9	6010532001011075	2003	-	28	-
5046451999009036	2002	11	22	8	6010532001011101	2003	-	36	-
5046481999990431	2002	16	18	2	6012501999907244	2003	-	63	-
5046482000001439	2002	12	32	10	60103220010Y1042	2003	-	43	-
5046521999990382	2002	8	30	12	601082199595B320	2003	-	29	-

Link sires are italicised.

9.5 Appendix 5. Pearson correlation coefficients for terminal cross carcass traits and Merino ram ASBVs

Correlation (R) between progeny group least square means of carcase characteristics of terminal crossbred lambs estimated in section 4 *(cold carcase weight (CCWT), GR thickness, carcase eye muscle depth (cEMD) and width (cEMW) and cfat)* and Merino ram ASBVs calculated in the Merino SG database in July 2007 *(PWWT, FAT, EMD). Italicised values are the level of significance (P=).*

	CCWT	GR	cEMD	cEMW	cfat	pHu	Glycogen	SF
PWWT	0.078	-0.098	-0.164	0.227	-0.090	0.109	0.124	0.009
	0.6626	*0.5832*	*0.3537*	*0.1962*	*0.6136*	*0.541*	*0.4834*	*0.9603*
FAT	0.098	0.272	0.062	0.112	0.162	0.097	0.066	-0.076
	0.5813	*0.1203*	*0.7259*	*0.5301*	*0.3605*	*0.5871*	*0.7126*	*0.668*
EMD	0.041	0.191	0.049	0.064	0.121	-0.122	0.200	-0.186
	0.8183	*0.2793*	*0.7845*	*0.72*	*0.4957*	*0.4918*	*0.2579*	*0.2922*

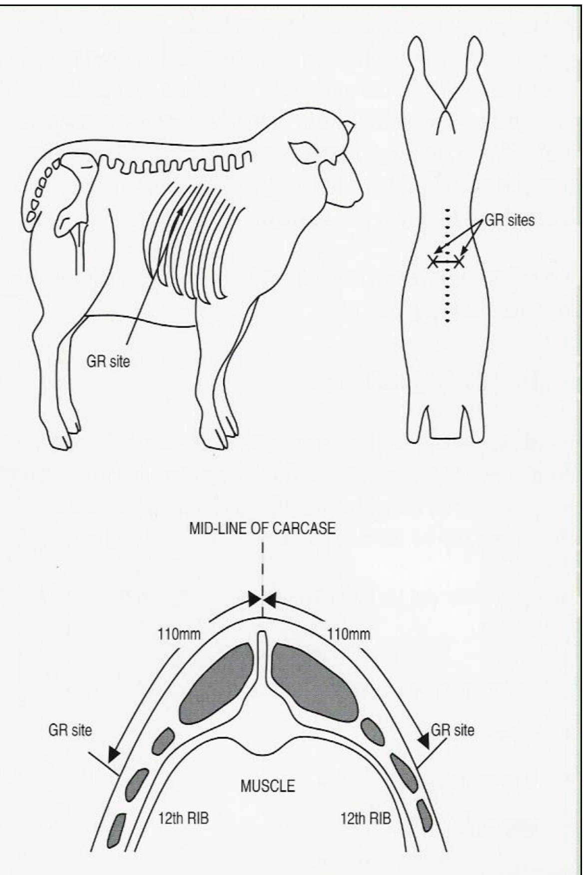
9.6 Appendix 6. Condition score and fat score assessment

Condition scoring sheep (from lifetimewool.com.au)

1 	**Backbone** The bones form a sharp narrow ridge. Each vertebra can be easily felt as a bone under the skin . There is only a very small eye muscle. The sheep is quite thin (virtually unsaleable)	**Short Ribs** The ends of the short ribs are very obvious. It is easy to feel the squarish shape of the ends. Using fingers spread 1cm apart, it feels like the fingernail under the skin with practically no covering
2 	**Backbone** The bones form a narrow ridge but the points are rounded with muscle. It is easy to press between each bone. There is a reasonable eye muscle. Store condition- ideal for wethers and lean meat.	**Short Ribs** The ends of the short ribs are rounded but it is easy to press between them. Using fingers spread 0.5cms apart, the ends feel rounded like finger ends. They are covered with flesh but it is easy to press under and between them.
3 	**Backbone** The vertebrae are only slightly elevated above a full eye muscle. It is possible to feel each rounded bone but not to press between them. (Forward store condition ideal for most lamb markets now. No excess fat).	**Short Ribs** The ends of short ribs are well rounded and filled in with muscle. Using 4 fingers pressed tightly together, it is possible to feel the rounded ends but not between them. They are well covered and filled in with muscle.
4 	**Backbone** It is possible to feel most vertebrae with pressure. The back bone is a smooth slightly raised ridge above full eye muscles and the skin floats over it.	**Short Ribs** It is only possible to feel or sense one or two short ribs and only possible to press under them with difficulty. It feels like the side of the palm, where maybe one end can just be sensed.
5 	**Backbone** The spine may only be felt (if at all) by pressing down firmly between the fat covered eye muscles. A bustle of fat may appear over the tail (wasteful and uneconomic).	**Short Ribs** It is virtually impossible to feel under the ends as the triangle formed by the long ribs and hip bone is filled with meat and fat. The short rib ends cannot be felt.

Fat scoring sheep

Description	Score	GR fat (mm)	Fist description
Individual ribs are easily felt and no tissue can be felt (sliding) over the ribs. Depressions are quite obvious between the ribs.	1	Less than 5	End of fingers – open hand.
Individual ribs are felt with some tissue able to be felt over the ribs. Depressions between ribs are obvious.	2	6-10	Knuckles – clenched fist.
Individual ribs can still be felt but they are more rounded, with tissue movement being felt over the ribs. The depression between ribs is less obvious.	3	11-15	Fingers between knuckles and first finger joint – open hand.
The ribs are less obvious to feel, with only some depression between the ribs. Tissue movement over the ribs is apparent.	4	16-20	Fingers between knuckles and first finger joint – clenched fist.
It is difficult to feel the ribs, or any depression between ribs. Sliding over the ribs is easy.	5	Greater than 20	Back of hand – clenched fist.



9.7 Appendix 7. Publications and communications

9.7.1 General

- "Re-shaping Merinos with management and genetics." Struan Research Centre Field Day. March 2004
- 8th Annual Merino Selection Demonstration Flocks Field Day, Turretfield Research Centre (14 April 2005) Poster display about SHGEN.027 to raise awareness of the project. Field Day had 142 registrants.
- Limestone Coast Grasslands Society forum on Beef, Sheep & Grass for this Millennium, Lucindale (7 April 2005). 20-minute presentation and poster display to approximately 40 participants entitled "Profiting from Merino ewes" that discussed all Struan based sheep research projects, including SHGEN.027.
- Stock Journal – General News (21 April 2005). Article written by journalist who attended Grasslands forum.
- "Merino genes and prime lamb production update" SA Lamb Newsletter (May 2005).
- "Increasing Merino Survival Rates" mlaProgr彼zier Summer 2006-07. p14.
- April 2007: Interaction between merino genes and environment and their effect on prime lamb production was mentioned in an overview of local research in SA at the Lucindale MLA Meat for Profit Day and results were on display and Janelle was available for discussion. Over 400 people attended this event
- "The Merino contribution to first cross lamb production". Presentation to SuperBorders Pre-Conference Activity at Turretfield Research Centre – 30 June 2006.

9.7.2 Scientific papers

Starbuck T.J and Hocking Edwards J.E. (2004) Merino rams influence the reproductive ability of their daughters. . In '25th Biennial Conference of the Australian Society of Animal Production'. Melbourne, Vic.

Hocking Edwards, J.E., Edwards N.J. and Starbuck, T.M. (2005) Merino Breeding Values – How do they compare? *Proc. Assoc. Advmt. Anim. Breed. & Genet.* 16: 389-392.

Starbuck T, Hocking Edwards J, Hinch G (2006) Measurement of temperament/fearfulness of lambs without the use of specialist equipment. In '26th Biennial Conference of the Australian Society of Animal Production'. Perth, WA.

Hocking Edwards, J.E., Gould, R.M. and Copping, K.J. (2008) Strategies to improve merino weaner survival. *Aust. J. Exp. Agric*. **48**:974-978.

9.7.3 Papers in preparation

Hocking Edwards, J.E., Gould, R.M. and Starbuck, TJ. Impact of Merino genes on reproduction in prime lamb production systems. *Aust. J. Exp. Agric.*

Hocking Edwards, J.E., Gould, R.M. and Starbuck, TJ. Impact of Merino genes on liveweight, growth rate, carcase traits and eating quality in prime lamb production systems. *Aust. J. Exp. Agric.*

Hocking Edwards, J.E., Gould, R.M., Starbuck, TJ. and Hinch G. Role of behaviour in prime lamb production systems. *Aust. J. Exp. Agric.*

9.8 Appendix 8. Abbreviations, acronyms and definitions

Abbreviation	*Description*
a*	Redness of meat
ASBV	Australian Sheep Breeding Value (EBVs calculated by Sheep Genetics)
B$	Border dollar Index- expressed as a dollar index value. Includes weaning weight, number of lambs weaned, maternal weaning weight (milk and mothering ability), yearling weight, fat, muscle and fleece weight measurements.
b*	Yellowness of meat
BL	Border Leicester
BLxMo	First cross progeny from Border Leicester ram mated to Merino ewe
BWT	Birth weight EBV
Bwt	Phenotypic birth weight
C+	Carcase Plus index - based on the weight, fat and eye muscle depth ASBVs at post-weaning age (7.5 months) with a relative emphasis of 60% PWWT, 20% PFAT and 20% PEMD.
CCWT	Cold carcase weight
cEMD	Carcase eye muscle depth
cEMW	Carcase eye muscle width
c-fat	Carcase fat thickness at the c-site
Conception rate	Number of foetuses present at scanning / number of ewes present at mating
CS	Condition Score
CTSE	Merino Central Test Sire Evaluation
D300wt	Phenotypic liveweight at approximately 300 days of age
EBV	Estimated breeding value
EMD	Eye muscle depth measured on the live animal by ultrasound scanning
Ewes pregnant	Number of ewes pregnant at scanning / number of ewes present at mating
Fat	Fat depth measured on the live animal by ultrasound scanning
First cross	First cross progeny from Border Leicester ram mated to Merino ewe
FWEC	Phenotypic number of total worm eggs present in lamb faeces
HCFW	Hogget clean fleece weight (410 -550 days of age)
HCWT	Hot carcase weight
HEMD	Hogget eye muscle depth (410 -550 days of age)
HFAT	Hogget fat thickness (410 -550 days of age)
HFD	Hogget fibre diameter (410 -550 days of age)
HWT	Hogget weight (410 -550 days of age)
L*	Lightness of meat
MCPT	Maternal Central Progeny Test
MGS	Merino Genetics Services (now Merino Select)
Mo	Merino
MWWT	Maternal weaning weight
NLW	Number of lambs weaned
PD	Poll Dorset
PDxBLxMo	Second cross progeny from Poll Dorset rams mated to BLxMo ewes
PDxMo	Terminal cross progeny from Poll Dorset rams mated to Merino ewes
PFAT	ASBV for postweaning (160 to 340 days of age) fat depth measured on the live animal by ultrasound scanning
pH120	pH of the carcase 120 hours after slaughter
pH24	pH of the carcase 20-24 hours after slaughter equivalent to ultimate pH
pHu	Ultimate pH of the carcase 20-24 hours after slaughter
PWWT	ASBV for post weaning weight (160 to 340 days of age)
Second cross	Second cross progeny from Poll Dorset rams mated to BLxMo ewes
SG	Sheep Genetics
Survival	Number of lambs present at weaning / Number of foetuses present at scanning
Terminal cross	Terminal cross progeny from Poll Dorset rams mated to Merino ewes
WWT	ASBV for weaning weight (40-120 days of age)
Wwt	Phenotypic weaning weight (approximately 100 days of age)
YEMD	Yearling eye muscle depth (290 -340 days of age)
YFAT	Yearling fat depth (290 -340 days of age)