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Interaction between Merino genes and environment and their effect on prime lamb production

Merino weaner growth path affects prime lamb production

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Abstract

This project was developed to provide prime lamb producers with information necessary to manage and optimise Merino genetics in their prime lamb production systems. Divergent Merino genetics and nutrition were contrasted and the interaction between environment and genotype was examined. Prime lamb producers can use Merino ram EBVs with confidence to improve liveweight and carcass weight in their terminal cross lambs. Merino EBVs can be used to compare the genetic potential of Merino weaners that have undergone different post weaning growth paths. Merino ewes that grow rapidly from weaning to 300 days of age have increased reproductive potential compared to those that follow traditional “merino-weaner” growth paths and should be used in prime lamb production systems to increase the number of prime lambs produced.

Executive Summary

This project was developed to provide prime lamb producers with information necessary to manage and optimise Merino genetics in their prime lamb production systems with a particular focus on the effect of genotype by environment (GxE) interactions on prime lamb production systems. Many breeders believe that GxE exists in sheep. With the development of a national genetic evaluation system for sheep (Sheep Genetics), it is necessary to understand the importance of GxE on different traits in different environments and to determine whether environmental conditions alter the estimated breeding values (EBVs) of sheep. It is possible that different management conditions affect EBVs that will not be expressed in a commercial environment. This project was embedded within SHEGN027 - *Influence of Merino genes on prime lamb production* and designed to test two hypotheses:

1. That GxE interactions do not affect prime lamb production systems; and

2. That prime lamb production can be increased by improving Merino ewe weaner nutrition.

Divergent Merino genetics and nutrition were contrasted and the interaction between environment and genotype was examined. Progeny from 13 Merino rams followed two nutritional post weaning growth paths to examine the expression of Merino genes under different environmental conditions with particular emphasis on growth paths of ewe weaners. Growth, health, carcass characteristics and reproductive performance of the progeny were examined. EBVs rather than the now standard ASBVs have been used in this project as the majority the breeding values were estimated prior to the introduction of ASBV terminology into the Australian sheep industry. Likewise, post weaning traits and hogget traits are focussed on as these are the important ages for traits in the prime lamb and merino industry, respectively.

A clear divergence in post weaning growth paths between the rapid growth ewes and the normal growth ewes and in the expression of Merino genes in both the Merino and terminal cross progeny provided an excellent model to test the proposed hypotheses.

Post weaning growth path of Merinos affected post weaning weight, hogget fleece weight and hogget fibre diameter directly reflecting differences in nutrition. Likewise there was a significant difference between Merino rams in their progeny's liveweight, carcass, wool and reproductive traits. There were few consistent interactions between growth path and Merino ram, indicating that there would be little re-ranking of these Merino rams' ewe progeny when managed under different environments.

Merino ewes that grow rapidly from weaning to 300 days of age had increased reproductive potential compared to those that followed traditional "merino-weaner" growth paths. This is the first time this has been demonstrated in the Merino ewe. The "Lifetime Wool" project has recently demonstrated that nutrition of adult ewe affects reproductive rate but the SHGEN028 project has shown that post weaning nutrition has a permanent effect on reproductive ability. Growth of Merino ewe weaners affected the number of foetuses conceived, independently of liveweight and condition score at mating. Weaner growth path did not affect lamb survival or lamb liveweights and there was no growth path by genotype effect.

Prime lamb production was influenced by Merino genetics in the terminal cross lambs, but growth path of their dams had little consistent effect on carcass characteristics. There was a slight increase in liveweight and carcass weight, although these differences were small.

EBVs for Merino PWWT, HCWT and HFD were comparable regardless of the post weaning growth path that the Merino weaners followed. This study has shown that for a sample of Merinos, the effects of different progeny growth paths were successfully removed in the production of EBVs. This project provides support for the ability of EBVs to remove the effect of environment from the phenotypic measurements of sheep and allow comparisons between

sheep regardless of the environment in which they were raised. The only exception to this is NLW.

To maximise reproductive performance of Merinos ewes it is necessary to utilise both genetics and nutrition management techniques. The results from this experiment have shown that post weaning nutrition has a consistent effect on conception rate with 10% more lambs conceived per year in the rapid growth ewes and fewer dry ewes at first mating. Merino sire also influenced conception rate as well as lamb survival but did not affect the ability of ewes to get pregnant. There was no interaction between growth path and Merino sire in most situations. It is therefore recommended that to maximise lamb production through reproductive performance it is necessary to identify rams that have high number of lambs weaned and then feed the ewes to continue to grow until their first mating at 18 months. However the ability to identify rams with high reproductive potential is difficult as in this trial Merino ram EBVs were not a good indicator of phenotypic measures of reproduction.

Prime lamb producers can use Merino EBVs with confidence to improve liveweight and carcass weight in their terminal cross lambs. There were no GxE interactions in liveweight and carcass traits, thus Merino EBVs can be used to compare the genetic potential of Merino weaners that have undergone different post weaning growth paths.

Increasing post weaning growth paths of Merino ewes could possibly contribute an extra 10% more lambs per year per flock. Merino ewes that grow rapidly from weaning to 300 days of age have increased reproductive potential compared to those that follow traditional “merino-weaner” growth paths and these ewes should be used in prime lamb production systems to increase the number of prime lambs produced. This project is the first to report this possibility for prime lamb production systems. This was an unexpected outcome as the original hypothesis was to maximise reproductive performance of Merino ewes by demonstrating the feasibility of mating Merino ewes as lambs to increase the potential number of prime lambs through increased mating opportunities.

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Contents

1 Background

This project was developed to provide prime lamb producers with information necessary to manage and optimise Merino genetics in their prime lamb production systems with a particular focus on the effect of genotype by environment (GxE) interactions on prime lamb production systems.

Many breeders believe that GxE exist in sheep. There is a small strain by environment effect however sire by environment effects have not been well defined in Merinos (reviewed by Carrick and Van der Werf 2007; Woolaston 1987). With the development of a national genetic evaluation system for sheep (Sheep Genetics), it is necessary to understand the importance of GxE on different traits in different environments and to determine whether environmental conditions alter the estimated breeding values (EBVs) of sheep.

Seedstock producers are more likely to ensure that their weaners grow well through summer and autumn, unlike commercial producers who are more concerned with flock performance rather than individual performance. Information collected by seedstock producers is then used to calculate breeding values. It is possible that different management conditions affect the estimated breeding values and these will not be reflected in the production of the progeny in a commercial environment.

Prime lamb producers mate first cross ewes at 8-9 months of age (and even earlier) to produce extra lambs in her lifetime, thus maximising the reproductive potential of first cross ewes. To do this, first cross ewe lambs are grown well through autumn and summer to attain 40kg liveweight by mating at 8-9 months of age. It is unusual for Merino ewes to be mated as lambs primarily because the Merino ewe weaners are not managed in a similar manner to the first cross ewe lambs and therefore do not reach a liveweight suitable for successful mating as lambs. Mating Merino ewes as lambs is possible and there are guidelines to undertake this (eg Marchant 2004) but it is very uncommon in Merino flocks.

This project was embedded within SHEGN027 - *Influence of Merino genes on prime lamb production* and designed to test two hypotheses:

1. That GxE interactions do not affect prime lamb production systems; and
2. That prime lamb production can be increased by improving Merino ewe weaner nutrition.

Divergent Merino genetics and nutrition were contrasted and the interaction between environment and genotype was examined. Progeny from 13 Merino rams followed two nutritional post weaning growth paths to examine the expression of Merino genes under different environmental conditions with particular emphasis on growth paths of ewe weaners. Growth, health, carcass characteristics and reproductive performance of the progeny were examined.

2 Project Objectives

- Identify the influence of environment on expression of Merino genes in prime lamb production systems.

- Increase lamb production through maximising genetic potential of Merino genes.

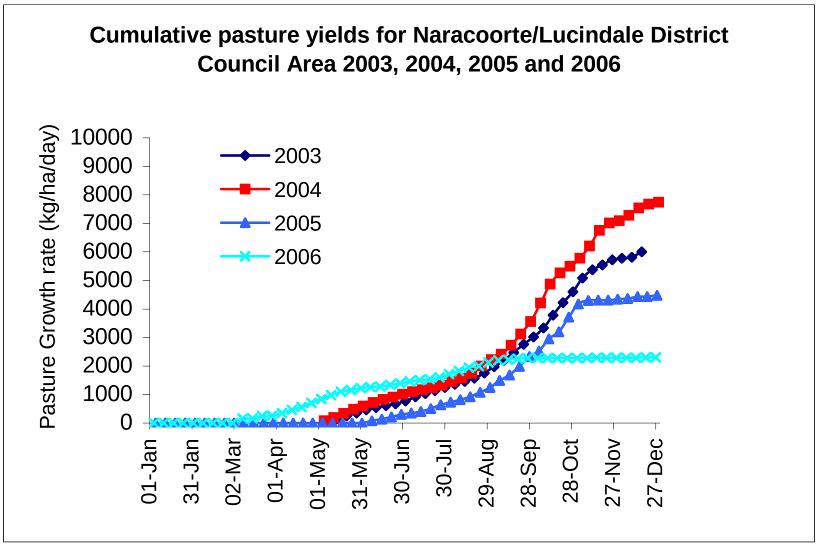
- Increase lamb production through maximising reproductive performance of Merino ewes.

3 Methodology

3.1 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 September 2003 and June 2007 with approval from the PIRSA Animal Ethics Committee.
Struan and Kybybolite Research Centres were in areas that have received Exceptional Circumstances Classification as a result of drought conditions from 2002 until the completion of this project. These conditions had an impact on the project during the autumn period of 2005 when it did not rain until mid June after lambing had commenced and pasture growth was very low (Figure 1). Lambing of the Merino ewes started in early June 2005 at a time when the season had not broken and the ewes were being 100% supplementary fed. There was no pasture of any value in the lambing paddocks and the ewes continued to be 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 1. 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.



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3.2 Sheep

Merino ewes were artificially inseminated with semen from Merino rams in 2003. Four rams were selected for their genetic diversity in reproduction, growth and wool production (Rams 2, 6, 7, 8; Table 1) and two rams were selected by a local industry group who identified two properties that they believed produced ideal “maternal” Merino ewes for their flocks (Rams 1 & 5; Table 1). The ewe lambs from an additional seven rams entered by commercial ram breeders into the 2003 Merino Central Test Sire Evaluation (CTSE) and one link sire for the CTSE were managed identically to the SHGEN028 progeny as part of SHGEN027 and have been included in this report to provide additional data for analysis as the two projects were conducted in parallel. Thus ewe progeny by 13 merino sires and wether progeny from the 6 rams were assessed in this project.

Table 1a. EBVs of Merino rams (Minimum and Maximum EBV for each trait highlighted in bold; accuracy (x 100) in parentheses) calculated by MGS in October 2005. WWT-weaning weight (kg); PWWT-post weaning weight (kg); HWT-hogget weight (kg); HCFW-hogget clean fleece weight (kg); HFD-hogget fibre diameter (um); N PROG-number of progeny used to calculate ram EBV; N FLOCK-number of flocks used to calculate ram EBV. * Central Test Sire Evaluation Rams

Ram No.	WWT	PWWT	HWT	HCFW	HFD	N PROG	N FLOCK
Ram 1	4.93 (93)	5.15 (93)	8.05 (93)	**-0.05** (95)	-1.49 (95)	121	1
Ram 2	**5.13** (98)	**7.80** (98)	**10.38** (97)	-0.09 (98)	-0.99 (98)	743	7
Ram 3*	1.65 (92)	2.74 (92)	2.44 (92)	0.17 (94)	-0.58 (94)	101	1
Ram 4*	1.41 (97)	1.31 (65)	1.47 (96)	0.59 (96)	-0.31 (98)	1125	6
Ram 5	3.51 (95)	2.43 (95)	1.64 (95)	0.26 (96)	-0.67 (96)	242	2
Ram 6	2.67 (98)	4.14 (97)	6.47 (98)	0.66 (98)	**0.64** (98)	721	14
Ram 7	3.66 (96)	2.63 (96)	0.79 (97)	0.37 (98)	-0.59 (98)	473	3
Ram 8	1.19 (96)	**-0.80** (97)	-0.30 (96)	0.07 (96)	**-2.37** (96)	444	2
Ram 9*	3.79 (96)	3.23 (96)	3.68 (95)	0.55 (95)	-1.32 (97)	414	5
Ram 10*	**0.95** (95)	2.80 (95)	4.2 (94)	0.32 (94)	-0.29 (96)	247	3
Ram 11*	1.21 (95)	-0.10 (95)	**-0.92** (95)	0.24 (96)	-1.06 (97)	200	2
Ram 12*	2.21 (96)	2.66 (95)	2.58 (95)	**0.79** (96)	0.06 (97)	328	2
Ram 13*	3.64 (91)	3.86 (90)	4.00 (90)	0.09 (93)	0.52 (93)	74	1

Table 1b. EBVs of Merino rams - continued. PFAT-post weaning fat depth (mm); PEMD-post weaning eye muscle depth (mm); HFAT-hogget fat (mm); HEMD-hogget eye muscle depth (mm); *Central Test Sire Evaluation Rams

Ram No.	PFAT	PEMD	HFAT	HEMD
Ram 1	-0.642 (86)	0.044 (86)	-1.167 (94)	0.646 (91)
Ram 2	-0.303 (97)	-0.075 (97)	-1.026 (98)	-0.463 (96)
Ram 3*	**0.543** (72)	**1.081** (57)	**2.217** (93)	**1.614** (89)
Ram 4*	-0.423 (82)	-0.414 (79)	-0.579 (93)	-0.492 (89)
Ram 5	-0.348 (91)	-0.491 (91)	-0.756 (95)	-1.049 (92)
Ram 6	-0.228 (93)	0.918 (92)	-0.180 (98)	1.287 (96)
Ram 7	-0.348 (89)	0.428 (86)	-1.179 (96)	0.335 (93)
Ram 8	0.210 (91)	0.308 (90)	0.390 (97)	0.095 (95)
Ram 9*	-0.354 (82)	0.227 (77)	-0.630 (93)	0.761 (89)
Ram 10*	**-0.951** (89)	**-1.318** (89)	**-1.923** (94)	**-2.039** (91)
Ram 11*	-0.63 (91)	-0.269 (91)	-0.732 (94)	-0.016 (91)
Ram 12*	-0.507 (91)	-0.361 (92)	-1.419 (95)	-0.601 (92)
Ram 13*	0.225 (70)	0.894 (56)	1.287 (93)	1.318 (88)

Lambs were born between 12 June and 8 July 2003 and ewe lambs were split into 2 groups (Rapid growth – n=295; Normal growth – n=296) at weaning by stratified randomisation based on sire, marking weight and birth type. The number of individuals per Merino ram group is listed in Appendix 1. Whilst green feed was available all progeny were allowed to grow to reach 30kg by the time of pasture senescence (Figure 2). This is the normal growth pattern that Merino weaners follow in a Mediterranean environment. By mid December the green feed had dried off and the sheep were supplemented with faba beans to supply additional protein. The rapid growth ewes were moved to irrigated pasture and the normal ewes were maintained on dry pasture and supplemented with faba beans from 175 days of age. The rapid growth ewes were mated at 230 days of age and managed separately from the normal growth ewes until weaning of the lambs from the rapid growth ewes in November 2004 (Average ewe age = 510 days). From this time on, the rapid growth and normal growth ewes were managed as a single mob, or when the mob needed to be split for mating or lambing, the ewes from the two growth paths were equally divided.

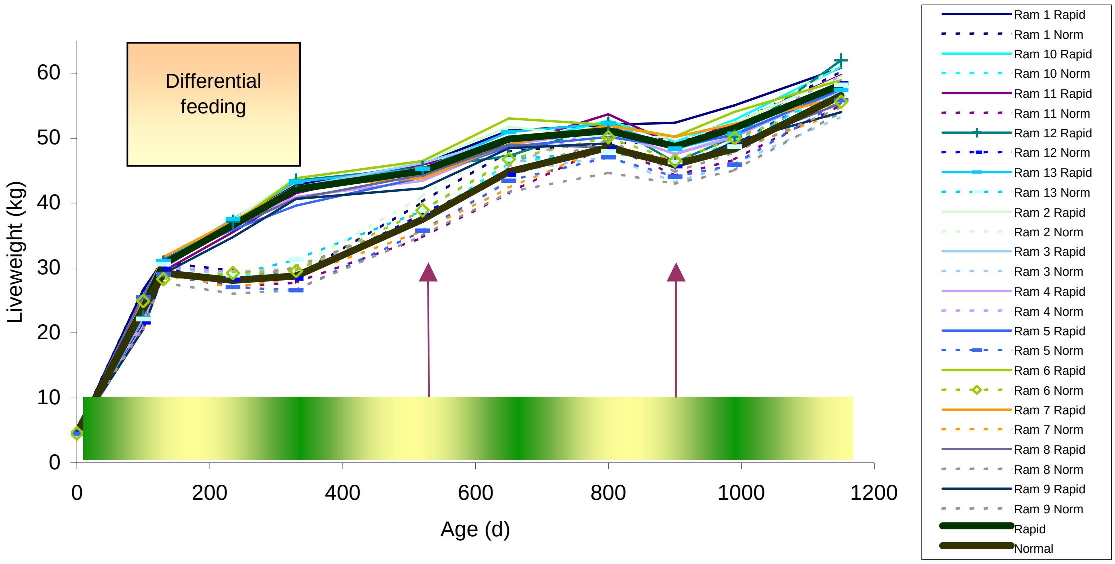

Figure 2. Growth of ewe lamb progeny from 13 sires following a rapid (solid) or normal (dashed) growth path. Mean liveweight of Normal and Rapid growth ewes are overlaid. Arrows indicate time of 1st and 2nd mating.

3.3 Production of prime lambs

3.3.1 Production of maternal first cross lambs

At 230 days of age, the rapid growth path ewe lambs on irrigated pasture were teased with testosterone-treated wethers for 20 days to stimulate follicle cycling. The ewe lambs were split into 8 groups by stratified randomisation based on Merino sire, liveweight and birth type. One Border Leicester ram was placed with each group for three weeks and the rams were rotated to a different group of ewes for the second three-week mating period. The rams used and their EBVs (provided by the ram seller from LAMBPLAN analyses undertaken in September 2002 for the 2001 drop rams and September 2003 for the 2002 drop rams) are shown in Table 2. Throughout the mating period the ewes were maintained on dry pasture and supplemented with beans (1.4kg/hd/d) and silage (0.5kg/hd/d). The rams were removed on 22 April 2004 after six weeks of mating. The ewes were pregnancy scanned on 31 May 2004.

Table 2. Lambplan EBVs (September 2002 and 2003 runs) of Border Leicester rams mated to ewe lambs. WWT-weaning weight (kg); HWT-hogget weight (kg); HGFW-hogget greasy fleece weight (kg); NLW- number of lambs weaned (%); YFAT - Yearling fat depth at the c-site (mm); YEMD – Yearling eye muscle depth at the c-site (mm); B$ - Border Index.

Border Leicester ram	WWT	HWT	HGFW	NLW	YFAT	YEMD	B$
0244122001011334	0.30	3.30	0.25	5.30	-0.10	-0.60	104.6
0244132001011270	0.00	3.30	-0.18	8.30	0.20	0.00	104.8
0244142001011429	0.30	2.20	0.27	7.50	-0.50	-0.20	105.5
0244112001011491	1.00	2.00	0.27	1.20	-0.10	0.40	104.4
0244152002022412	1.80	1.40	0.00	4.70	0.50	0.20	107.5
0244162002022388	0.90	3.40	0.00	5.80	0.50	0.40	107.4
0244172002022367	0.70	2.50	0.30	6.90	0.50	0.20	107.0
0244182002022423	1.10	3.10	0.20	7.50	0.10	0.00	107.6

One week prior to the expected commencement date of lambing, the rapid growth ewes were drafted into sire groups and placed into separate lambing paddocks. Stocking rate and FOO were managed to provide equivalents amounts of feed for each sire group during lambing. Ewes were checked daily and lambs were tagged and weighed within 24h of birth. When lambing was complete all groups were recombined into a single mob and the lambs were marked on 15 October 2004 (average age = 6 weeks). Lambs were weaned at an average age of 11 weeks.

3.3.2 Production of terminal crossbred lambs

The rapid and normal growth ewes were mated at 20 months and three years of age to Poll Dorset rams (Table 3) to produce terminal cross lambs. Ewes were placed with testosterone-treated wethers for 14 days and then divided into groups of 37-43 with progeny from each sire split equally between groups. 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. At the completion of mating, the rams were removed and the ewes 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 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.

Table 3. Lambplan EBVs (September 2002 and 2003) of Poll Dorset rams mated to Merino ewes. WWT-weaning weight (kg); PWWT-post weaning weight (kg); PFAT – Post weaning fat depth at the c-site (mm); PEMD – Post weaning eye muscle depth at the c-site (mm); Carc+ - Carcass Plus Index.

Sire code	WWT	PWWT	PFAT	PEMD	Carc+
1622482002002339	4.14	8.90	-0.17	-0.05	156.1
1622482002002358	4.35	9.34	0.25	0.37	156.0
1622482002002416	3.68	6.42	-0.19	1.36	155.7
1622482002002419	4.85	7.38	-0.19	0.89	156.9
1622482002002429	4.19	7.47	-0.32	0.46	155.1
1622482002002431	4.49	6.90	-0.35	1.96	167.4
1622482002002475	3.48	5.50	-0.2	2.03	157.3
1622482002002494	3.47	7.00	-0.37	0.68	155.4
1622482002002514	4.11	8.51	-0.47	0.67	166.0
1622482002002615	3.52	7.10	-0.56	0.36	155.8
1622482003033256	4.17	6.42	-0.67	1.63	166.5
1622482003033262	-	9.30	-0.50	0.20	168.0
1622482003033310	-	8.20	-0.80	0.80	171.0

3.3.3 Production of second cross lambs

The 30 first cross ewe lambs (BLxMo) produced from the rapid growth ewes in 2004 were mated to Poll Dorset rams at 20 months of age. Ewes were placed with testosterone-treated wethers for 14 days and prior to mating to ram X (Table 4) for three weeks. After this time, ram X was removed and ram Y (Table 4) was placed with the ewes for three weeks also. 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.

Table 4. Lambplan EBVs (September 2002 and 2003) of Poll Dorset rams mated to BLxMo ewes. WWT-weaning weight (kg); PWWT-post weaning weight (kg); PFAT – Post weaning fat depth at the c-site (mm); PEMD – Post weaning eye muscle depth at the c-site (mm); Carc+ - Carcass Plus Index.

	Sire code	WWT	PWWT	PFAT	PEMD	Carc+
Ram X	**1622482002022498**	4.65	9.42	-0.49	1.00	175.3
Ram Y	**1622482003033310**	-	8.2	-0.8	0.8	171

One week prior to the expected commencement date of lambing, the ewes were checked daily and lambs were tagged and weighed within 24h of birth. The lambs were weighed and marked at an average age of 6 weeks and weighed and weaned at an average age 12 weeks.

3.4 Prime lamb live animal measurements

After weaning, the 2005-drop terminal crossbred lambs were grown on irrigated pasture until slaughter at approximately 300d of age. 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 were calculated by a commercial laboratory. Liveweights were recorded at six to eight weekly intervals between weaning and slaughter and fat and eye muscle depth of the lambs was measured using real time ultrasound scanning prior to slaughter.

3.5 Carcass measurements

A total of 604 terminal cross lambs were slaughtered at Bordertown by Tatiara Meat Company and the hot carcass weights (HCWT) were recorded by the abattoirs central system. A list of the Merino rams and the number of carcass is in Appendix 1. Carcasses were hung in a 2^oC chiller for 20hrs and then the carcasses were weighed on a hanging scale and cold carcass weights (CCWT) were recorded. After weighing, GR thickness was measured at the 12^{th} rib and then the carcasses were cut between the 12^{th} and 13^{th} rib. Eye muscle depth (EMD) and width (EMW) and c-fat thickness 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). Approximately 100g of loin caudal to the cut was removed and allowed to bloom for 30 minutes before L*, a* and b* were measured (Minolta chromameter, CR 300). 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 flim and aged at 4^oC for a further 4 days. The loin was then frozen and stored at -20^oC for subsequent analysis of shear force and glycogen potential.
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: 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.

3.6 Data analysis

Post weaning traits and hogget traits were focussed on in this report, as these are the important ages for traits in the prime lamb and merino industry, respectively. They are also related to the timing of the actual phenotypic measurements.

The data was analysed as a fixed effect model using REML in SAS. The objective of this analysis was to determine the influence of Merino ewe growth path on prime lamb production. The main effects in the model were growth path, Merino ram, Poll Dorset ram, sex (female, wether) and rear type (single, multiple). Birth type replaced rear type as a main effect for birth weight and reproductive factors. WEC was ln transformed and the back transformed results are presented in this report.

Age was included as a linear covariate for carcass weight and cold carcass weight and age were included as a linear covariate for the other carcass measurements. Two-way interactions were included in the model and removed from the model if not significant ($P<0.05$).

Analysis of variance was used to determine the impact of weaner nutrition and Merino sire on reproductive performance. The number of pregnant ewes, number of foetuses conceived and number of lambs weaned per ewe mated and the number of lambs weaned per foetus scanned were the variables in the model. Year of joining was used as the replicate. The Merino ewes from SHGEN028 have been included in the CRC for Sheep Industry Innovation Information Nucleus Flock (INF) and some of this reproduction data has been included in this report to assess the long-term effect of post weaning nutrition on reproduction. Pregnancy scanning results from the artificial insemination program of the INF followed by a natural 5-week backup joining in 2007 were included in the analysis of conception rate and proportion of pregnant ewes. However, the number of lambs weaned and lamb survival from this mating are not included as these results were not available at the time of writing the report.

Merino EBVs were calculated by Merino Genetic Services (now Sheep Genetics) in October 2005 using data collected on the individual progeny and all other related data. Terminal crossbred lamb EBVs were calculated by Sheep Genetics Australia (now Sheep Genetics) in June 2007 using data collected on the individual progeny and all other related data. EBVs rather than the now standard ASBVs were used predominantly in this project report as the majority of the breeding values were estimated prior to the introduction of ASBV terminology into the Australian sheep industry.

4 Results and Discussion

4.1 Effect of genotype and weaner growth path on phenotypic measurements.

4.1.1.1 Merino progeny

4.1.1.1.1 Liveweight and condition score

Merino ewe weaners that maintain liveweight through their first summer/autumn have lower liveweights and condition than Merino ewe weaners that are allowed to grow during the same period.

Sheep that underwent a Rapid growth path between weaning and 300 days of age were significantly heavier than the sheep that followed a Normal growth path from 300 days of age until their final weighing. There was a clear divergence in growth paths between the rapid growth ewes and the normal growth ewes (Figure 2.) There was no difference in liveweight at weaning (day 100), however, from 300 days of age, the rapid growth ewes were always significantly heavier than the normal growth ewes (P<0.0001) until the second mating of the ewes in 2006. There was some compensatory growth in the normal growth ewes, however, in March 2007, the ewes were weighed and the Rapid growth ewes were still 2.7kg heavier than the normal growth ewes (P = 0.006). Others have reported similar continued differences in liveweight after restrictions in postweaning nutrition until 7 years of age (Reardon and Lambourne 1966).

Rapid growth ewes had a higher CS than normally grown ewes at 330 days of age, maiden mating and mid pregnancy of the first and second mating (Table 5). However the differences between growth paths from maiden mating onwards were less than 0.12 of a CS which is unlikely to have a biological effect.

There was a significant difference in liveweight of ewe progeny from different Merino sires at all times of measurement (P<0.01) and a significant sire effect on CS at all time points measured with the exception of lamb weaning after their first mating (Table 5). The variation in CS was much greater between sires than between growth paths and this effect was present until the end of the measurement period. Correlations between carcass traits and CS are described in detail in SHGEN027 Final Report where more animals can be included in the analysis.

There was no interaction between growth path and Merino sire until the final measurement in March 2007 when the ewes were 3 years and 8 months of age (P=0.022). Likewise, there was no growth path by sire interaction on CS at any of the time points. Thus, in this trial post weaning growth path did not affect the ranking of rams for liveweight or CS of their ewe progeny.

Table 5. Mean condition scores (CS±SEM) of ewes at mating, mid pregnancy and weaning, grown under normal or rapid post weaning growth paths, the level of significance of growth path and sire on CS and the range in average CS of ewe progeny within growth paths from 13 different Merino sires.

	CS			Sire effect	Range between sires	
Timing	**Normal**	**Rapid**	**P=**	**P=**	**Normal**	**Rapid**
330 days of age	2.1 ± 0.03	3.2 ± 0.03	<0.001	<0.001	0.58	0.48
Maiden mating	2.9 ± 0.03	3.0 ± 0.03	0.017	<0.001	0.46	0.62
Mid pregnancy	2.8 ± 0.02	2.9 ± 0.02	0.008	<0.001	0.24	0.36
Weaning	2.7 ± 0.04	2.7 ± 0.04	ns	ns	0.46	0.57
Second mating	2.4 ± 0.03	2.4 ± 0.03	ns	<0.001	0.39	0.39
Mid pregnancy	2.7 ± 0.03	2.8 ± 0.03	0.001	0.007	0.43	0.40
Weaning	2.8 ± 0.02	2.8 ± 0.02	ns	0.005	0.54	0.20
Third mating	2.6 ± 0.03	2.6 ± 0.03	ns	0.002	0.58	0.48

4.1.1.1.2 Weaner survival

Feeding weaners to gain weight over the summer/autumn period (rapid growth) resulted in 5% more weaners surviving to the break of the season (Table 6.). The rapid growth path had 4% more weaners survive to hogget shearing compared to the traditional growth weaners and more ewes than wethers survived to hogget shearing. There was more of an effect of growth path on ewe hogget survival than on wether hogget survival as 5% more rapid growth ewes survived whereas only 2% more rapid growth wethers survived to hogget shearing compared to normal growth hoggets.

Table 6. Mortality of Merino weaners to the break of the season in May 2004 and to their hogget shearing. Rapid growth weaners were supplementary fed to reach 40kg by the break of the season and Normal growth weaners were fed to maintain liveweight over summer/autumn. Rapid wethers, and Normal growth ewes and wethers were run together as a single mob from the break of the season.

	Number of sheep present at				Mortality	
	Weaning	Differential feeding start	Break of season	Hogget shearing	Weaning to break of season	Weaning to hogget shearing
Rapid ewes	311	309	301	294	3%	5%
Rapid wethers	168	167	158	149	5%	11%
Rapid growth	**479**	**476**	**459**	**443**	**4%**	**7%**
Normal ewes	309	309	289	279	6%	10%
Normal wethers	479	475	430	415	10%	13%
Normal growth	**788**	**784**	**719**	**694**	**9%**	**11%**

Despite feeding weaners well after weaning, there was no decrease in mortality of weaners that were lighter than 20kg at weaning (Figure 3 & Table 7). Also, more single born lambs that weighed less than 20kg at weaning died than twinborn lambs at similar weaning weights (Table 7.). This suggests that the light single born lambs may have had a serious set-back prior to weaning such as mismothering and very little can be done to ensure the survival of these weaners in a commercial environment.

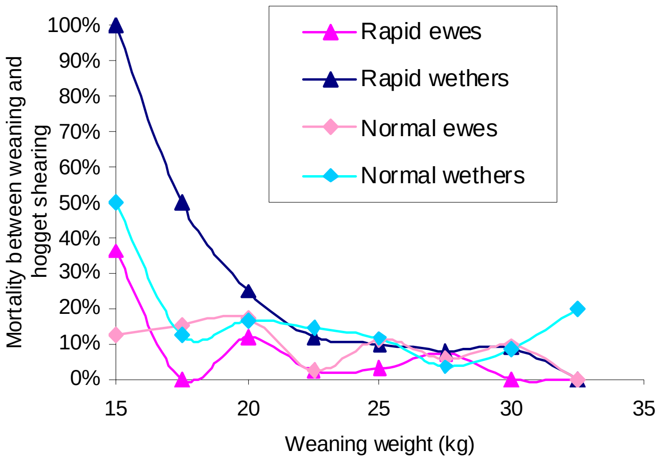

Figure 3. Mortality of weaners between weaning and hogget shearing that followed either a rapid or normal growth path post weaning

Table 7. Number and mortality of single-born and twinborn weaners that were lighter than 20 kg or 20kg and greater at weaning fed to grow rapidly or normally over summer/autumn.

	N	Total	Single born	Twin born
	Weaning weight less than 20kg			
Rapid	46	24%	35%	15%
Normal	103	17%	22%	10%
	Weaning weight greater than 20kg			
Rapid	433	6%	6%	6%
Normal	686	10%	13%	7%

4.1.1.1.3 Wool production

Hogget wool production: The sheep on the rapid post weaning growth path grew 1.2 kg more clean wool (HCFW) that was 1.5um broader than the sheep on the normal growth path (P<0.0001) at hogget shearing. There was a significant effect of Merino ram on HCFW (P<0.0001) and HFD (P<0.0001; Table 8). This indicates that there was an effect of genotype (Merino ram) and environment (growth path) on hogget wool production in these sheep.

Table 8. Mean (±SEM) fleece characteristics of progeny groups from 13 Merino sires. Weaners were grown under normal or rapid post weaning growth paths. CFW - clean fleece weight (kg); FD – fibre diameter (um); H – hogget; A - adult.

	HCFW		**HFD**		**ACFW**	**AFD**
Merino ram	**Rapid**	**Normal**	**Rapid**	**Normal**		
Ram 1	3.82 ± 0.074	2.90 ± 0.077	18.1 ± 0.15	16.9 ± 0.16	3.24 ± 0.070	19.2 ± 0.18
Ram 2	3.90 ± 0.066	2.90 ± 0.069	18.5 ± 0.14	17.1 ± 0.14	3.19 ± 0.058	19.4 ± 0.15
Ram 8	4.07 ± 0.068	2.94 ± 0.068	17.6 ± 0.14	16.3 ± 0.14	3.30 ± 0.054	18.5 ± 0.14
Ram 5	4.14 ± 0.077	3.01 ± 0.071	18.8 ± 0.16	17.2 ± 0.15	3.60 ± 0.561	19.8 ± 0.14
Ram 7	4.22 ± 0.077	3.14 ± 0.064	18.9 ± 0.16	17.3 ± 0.13	3.40 ± 0.056	19.3 ± 0.14
Ram 13*	4.28 ± 0.119	3.15 ± 0.076	19.5 ± 0.25	18.0 ± 0.16		
Ram 6	4.31 ± 0.073	3.27 ± 0.076	19.8 ± 0.15	18.0 ± 0.16	3.43 ± 0.064	20.1 ± 0.16
Ram 3*	4.47 ± 0.126	3.19 ± 0.068	18.6 ± 0.26	17.5 ± 0.14		
Ram 11*	4.50 ± 0.116	3.08 ± 0.076	18.9 ± 0.24	17.1 ± 0.16		
Ram 9*	4.54 ± 0.096	3.49 ± 0.053	18.4 ± 0.20	17.2 ± 0.11		
Ram 10*	4.68 ± 0.126	3.11 ± 0.080	19.4 ± 0.26	17.4 ± 0.16		
Ram 4*	4.79 ± 0.139	3.59 ± 0.079	18.7 ± 0.29	17.2 ± 0.16		
Ram 12*	5.16 ± 0.134	3.46 ± 0.073	19.4 ± 0.28	17.9 ± 0.15		
Average	*4.38 ± 0.030*	*3.17 ± 0.020*	*18.8 ± 0.06*	*17.3 ± 0.04*		

There was no interaction between sire and growth path for HCFW, indicating post weaning growth path did not affect the ranking of rams for these measurements. However, there was a significant interaction between Merino ram and growth path on HFD (P=0.004). These results suggest that progeny from these rams will be consistently ranked for HCFW regardless of their post weaning growth path but there may be some re-ranking of the rams for HFD. Rank correlations were significant for both HCFW (P=0.008) and HFD (P=0.004) further indicating that there is little re-ranking of rams' progeny from the two different growth paths. The rank correlation analysis is consistent with the analysis of variance results for no GxE interaction for HCFW but the conclusions from the two analyses of HFD are inconsistent.

Adult wool production: Wool samples were collected and fleece characteristics were measured on the progeny of the six SHGEN028 rams in 2005 and 2006 to assess whether there was any interaction between ewe weaner growth path, Merino ram and pregnancy and lactation. There were significant Merino sire effects on adult clean fleece weight and fibre diameter (Table 8), but no carry over effect of post weaning nutrition on adult fleece production. There was a significant year effect with ewes producing 0.5kg more clean wool that was 1.5um broader in 2006 compared to 2005. Dry ewes produced 0.4kg more wool than pregnant ewes but there was no difference in fibre diameter between pregnancy status. There was no post weaning nutrition, year or pregnancy status interaction with Merino sire.

4.1.1.1.4 Reproduction

A summary of the fertility (proportion of pregnant ewes), fecundity (number of foetuses present at scanning; conception rate), survival of lambs from scanning to weaning and number of lambs weaned per ewe mated per year is presented in Table 9. Only 31% of the Merino ewe lambs

were pregnant at scanning in 2004 (Table 9). The ewes were gaining weight going into and throughout mating and had an average fasted liveweight of 39.2kg and condition score of 3.14, which should theoretically be the ideal condition in which to mate. The low conception rates may be due to the ewes not reaching puberty prior to mating or due to the change in feed from irrigated pasture to dry pasture plus supplement during mating. This mating was not included in any further analysis due to the low number of progeny produced.
Although the number of rapid growth ewes that became pregnant at the 8-month mating was low, there were not any adverse effects on fertility, in fact their fertility was generally greater than the ewes on the normal growth path. Of the rapid growth ewes that weaned a live lamb from their mating at 8 months of age, 80.5% of them became pregnant again at their second mating at 18 months of age. Likewise there was not any adverse effect of losing a lamb from the early mating on their ability to become pregnant at the second mating.

Table 9. Proportion of pregnant ewes, conception rate, survival of scanned foetuses to weaning (foetal survival) and lambs weaned (NLW) from ewes from 13 Merino sires. Ewes were grown under normal or rapid post weaning growth paths.

	N ewes[#]		Pregnant ewes [a]		Conception [a]		Foetal survival [b]		NLW [b]	
	Normal	**Rapid**	**Normal**	**Rapid**	**Normal**	**Rapid**	**Normal**	**Rapid**	**Normal**	**Rapid**
Growth path	296	295	83%	87%	98%	109%	69%	68%	57%	64%
			P=0.083		*P=0.001*		*P=0.953*		*P=0.067*	
Year 2004			-	31%	-	38%	-	57%	-	21%
2005	242	259	79%	88%	86%	105%	55%	52%	48%	54%
2006	242	259	78%	82%	81%	88%	82%	85%	67%	74%
2007	227	231	90%	90%	126%	135%	-	-	-	-
			P=0.003		*P=0.072*		*P<0.0001*		*P<0.0001*	
Merino sire										
Ram 1	31	29	72%	86%	82%	111%	56%	62%	44%	57%
Ram 2	23	22	79%	90%	102%	109%	78%	87%	66%	78%
Ram 3*	31	31	84%	84%	100%	108%	79%	73%	64%	74%
Ram 4*	13	15	81%	88%	95%	109%	74%	73%	56%	68%
Ram 5	19	20	76%	83%	93%	99%	55%	66%	38%	56%
Ram 6	28	26	94%	91%	109%	132%	78%	69%	73%	77%
Ram 7	33	31	77%	92%	92%	130%	61%	63%	51%	73%
Ram 8	32	31	82%	80%	97%	103%	68%	70%	53%	59%
Ram 9*	15	15	86%	88%	98%	98%	71%	80%	64%	73%
Ram 10*	16	18	95%	83%	106%	106%	82%	66%	75%	52%
Ram 11*	21	22	84%	92%	96%	115%	53%	52%	46%	54%
Ram 12*	15	17	84%	79%	92%	90%	65%	66%	56%	50%
Ram 13*	19	18	84%	90%	111%	112%	71%	64%	60%	63%
			P=0.458		*P=0.054*		*P=0.020*		*P=0.070*	

Number of ewe weaners present at the start of the feeding treatments
[a] three matings; [b] two matings.

Seven percent more lambs were weaned from ewes that underwent a rapid post weaning growth path compared to the normal growth ewes (Table 9). As mentioned earlier, this was not due to more lambs that were produced from the 8 month old mating in 2004, since this reproductive event was not included in the following analysis. Rather, the increased reproductive performance was a result of 11% more lambs conceived and fewer dry ewes, particularly at their 18 month-old "maiden" mating in 2005. It is possible that post weaning growth path in Merino ewes has a long term effect on ovarian follicle function as more twins were conceived in the rapid growth ewes. This result supports that observed in Corriedales (Coop and Clarke 1955), fine wool Merinos (Reardon and Lambourne 1966), and Brecon Cheviot ewes (Rhind *et al.* 1998). In a comparison of severe growth restriction during early post-natal life of Merinos with a normal "traditional" Mediterranean growth path (Allden 1979), there were no long term effects on reproduction in later life. Allden suggested that the unrestricted controls produced more twins than the restricted groups but his results were not significant. It is possible that any type of growth check during the postnatal/pre-pubertal period is enough to decrease fertility compared to continuous growth from birth to puberty.

There were more dry ewes in the normal growth path at their maiden mating but this was not observed at the second or third mating. Thus post weaning growth path may affect onset of puberty but does not appear to have long-term effect on ability to conceive as the number of dry ewes declined over time. In sheep, final maturation and growth of the uterine wall does not occur until puberty (Kennedy *et al.* 1974) or possibly until first pregnancy (Stewart *et al.* 2000). It is possible that post weaning nutrition has influenced the development of the uterus. However there does not appear to be any long term effects as there were no differences in the number of ewes pregnant at scanning by the third mating. Alternatively the higher proportion of dry ewes in the earlier matings of the normal growth ewes may have been failure to ovulate or due to a delayed puberty as a resultant of "low" nutrition (Foster *et al.* 1989).

A simple cost-benefit analysis is outlined in Table 10 and is based on actual feed costs in 2003 when the feeding trial was undertaken. This analysis assumes that there is similar survival rate of lambs from ewes from both growth paths between scanning and weaning (Table 9). Differences in Merino weaner survival as a result of the supplementation have not been taken into account. In the scenario below, there is a benefit of $2/ewe over the lifetime of the ewe to feed her to grow rapidly from weaning to 300 days of age. If the high cost of beans can be replaced, for example with a cereal, the profitability may improve. However, the response of an energy rich diet compared to the protein rich diet is unknown. There may also be a small trade-off in higher maintenance requirements of the heavier rapid growth ewes. Based on grain prices in 2007 there would be a $6/hd loss if weaner ewes were fed at the rate used in this project.

Table 10. Simple benefit-cost analysis of feeding Merino ewes to follow a rapid or normal growth path from weaning to 300 days of age and their subsequent reproductive ability when mated to terminal rams.

	Cost ($/t)	Feed offered (kg)		Cost/hd		Difference
Feed		**Rapid**	**Normal**	**Rapid**	**Normal**	
pasture	$ 17	569	377	$ 9.66	$ 6.42	
irrigated	$ 20	137	0	$ 2.74	$ -	
beans	$ 200	111	68	$ 22.16	$ 13.62	
silage	$ 80	35	0	$ 2.80	$ -	
Cost/hd				$ 37.37	$ 20.04	$ 17.33
Cost/1000 ewes				$ 37,369	$ 20,037	
Assume additional 10% more lambs from rapid ewes and 1000 ewe flock						
Assume $47/hd profit from lambs sales*						
		NLW	NLW			
2yo		770	700	$ 36,190	$ 32,900	
3yo		935	850	$ 43,945	$ 39,950	
4yo		946	860	$ 44,462	$ 40,420	
5yo		946	860	$ 44,462	$ 40,420	
6yo		935	850	$ 43,945	$ 39,950	
Income				$ 213,004	$ 193,640	
Profit/1000 ewe flock				$ 175,635	$ 173,603	$ 2,032

*This accounts for (i) the feed required for the extra pregnant ewes (ii) additional feed required for the extra lactating ewes (iii) the reduction in wool cut and fibre diameter of the ewes pregnant or lactating with the extra lambs (J. Young, Lifetime Wool Decision Support Tools, pers. comm.)

Merino sire had a significant effect on foetal survival to weaning (P=0.020) and tended to have an impact on number of lambs conceived (P=0.054) and lambs weaned (P=0.070; Table 9). It was not possible to analyse the effect of litter size on survival as there were too few twin bearing ewes. There was no Merino sire effect on the ability of their ewe progeny to become pregnant. There was a significant year by sire interaction in the number of lambs weaned (P=0.008) and lamb survival (P=0.002). There was no interaction between year and sire in the proportion of dry ewes or number of lambs conceived when three years data was analysed.

In the group of sires tested, there were no GxE interactions as their ewe progeny respond similarly to different weaner growth path. There was no interaction between Merino ram and ewe growth path on proportion of ewes that conceived, conception rate, foetal survival or number of lambs weaned.

Impact of season on reproduction. Survival rates of the terminal cross lambs in 2005 were low (Table 9) as a result of the extremely late break to the season in 2005, with only 21% of twins and 63-66% of singles surviving. Between mating and pregnancy scanning (day 90; 7 April 2005) the ewes maintained condition score of 2.9. Condition score was not assessed after scanning, but from scanning until mid way through lambing, ewes were fed barley (750g/hd/d). This level of supplement would have resulted in a loss of 0.2 of a condition score/month (as modelled with Grazfeed). Decisions on feed requirements were made on the assumption that green feed would be available by the time lambing started (as is the norm in a typical season) and the ewes would have been at condition score 2.9 at lambing. However, at lambing the ewes were in average condition score of 2.5. This is lower than recommended (CS 3.0 is ideal) but not seriously low. This is demonstrated by a ewe mortality rate of 3.7% during lambing. Lamb birth weights were lower than the previous years maiden ewes (4.1 vs 4.8 kg), so there was an effect of the season on birth weight. Lambing observations indicate that the low lamb survival rate was due to the lack of interest of the ewes in their lambs. If the lamb did not follow the ewe, then she was not going to look for it. This was most obvious during the early part of lambing prior to rain. During lambing rounds several healthy lambs would be sitting alone in the paddock with no ewe in sight or interested in the lamb. Even when the mob was drifted back to the unclaimed lamb or the lamb moved to the mob, rarely did the ewes reclaim the lamb. The level of supplementary feeding we provided our research ewes was considerably more than we have feed in previous years and was similar to the level fed in our Lifetime Wool trial. With such a high dependence on supplementary feeding, poor maternal behaviour could be probably have been anticipated in this instance. Strategies that could have been implemented to increase survival include feeding ewes to maintain condition throughout pregnancy, rather than allowing loss of condition in anticipation of the ewes being able to regain weight on green feed (lifetimewool recommendations), and provision of self-feeders available to the ewes so that feeding during lambing does not cause more problems than it is trying to prevent.

The poor season of 2005 appears to be carried over to the condition of the ewes at mating in January 2006. The ewes did not recover condition from weaning in September 2005 to January 2006, so they were in less than ideal condition at their second mating (Table 7). This is reflected in their conception rates, with only 81% of the ewes scanned pregnant in April 2006 and only 4% of the ewes carrying twins.

Relationship between conception rate and liveweight and CS at mating. Heavier ewes in better condition are more likely to get pregnant when mated at 18 months of age. Within growth paths, there was a good relationship between liveweight and the number of foetuses in the normal growth ewes as would be expected. However in the rapid growth ewes the mean liveweight of the ewes that did not become pregnant was the same as those that were scanned with a single foetus but they had a lower condition score (Table 11). Generally, it can be concluded that there is a penalty of not meeting mating weight targets of 40kg and CS 3.0 and ideally the targets should be a minimum liveweight of 40kg and minimum condition score of 3.0 to achieve optimum fertility. However, the 12% of the rapid growth ewes that failed to become pregnant had a similar condition score and were heavier than those that became pregnant in the normal growth path. There are obviously factors affecting fertility other than liveweight and condition score.

Table 11. Proportion of Merino ewes scanned with 0, 1 or 2 foetuses, their liveweight (Wt) and condition score (CS) at mating (LSM ± SEM) after following a rapid or a normal growth path (the rapid growth ewes in this table only include data from those that were not scanned as pregnant at 8 months of age).

Growth path	N foetuses	0	1	2	Total N
Rapid	Proportion preg	11.9%	67.0%	21.1%	109
	Wt (kg)	46.7±1.43	46.8±0.60	50.3±1.08	47.9±0.63
	CS	3.0±0.12	3.2±0.05	3.2±0.09	3.1±0.05
Normal	Proportion preg	25.0%	67.3%	7.7%	156
	Wt (kg)	38.7±0.83	43.0±0.50	44.2±1.49	42.0±0.59
	CS	2.7±0.07	3.0±0.04	3.0±0.13	2.9±0.05

The difference in potential number of lambs from ewes from the two weaner growth paths was independent of CS differences between the two growth paths. There was no significant difference in overall CS at mating, nor for each number of foetuses at scanning. Overall the rapid growth ewes were 2.4kg heavier at mating (P<0.0001) and the rapid growth ewes carrying a single lamb were significantly heavier than normal growth ewes carrying a single lamb (P<0.0001). However there was no difference between growth paths of liveweight of the dry ewes or ewes carrying twin lambs at scanning.

The difference in reproductive potential of the ewes from the two different growth paths has several implications. The number of foetuses/100 ewes at each condition score followed similar curvilinear trends (Figure 4) to that reported previously (Kelly and Croker, 1990), however at both matings the curve moved up the y-axis with increasing weaner nutrition. This means that ewes that follow a rapid growth path after weaning are likely to have more lambs at any given condition score than ewes that follow a normal growth path. Furthermore, the slopes of the curves differ. At hogget mating the number of foetuses/100 ewes was more responsive to differences in CS in the normal growth ewes, but at the second mating the rapid growth ewes were more responsive to different condition scores. This may explain some of the variation in the relationship between CS and reproductive rate between properties observed in the lifetime wool project.

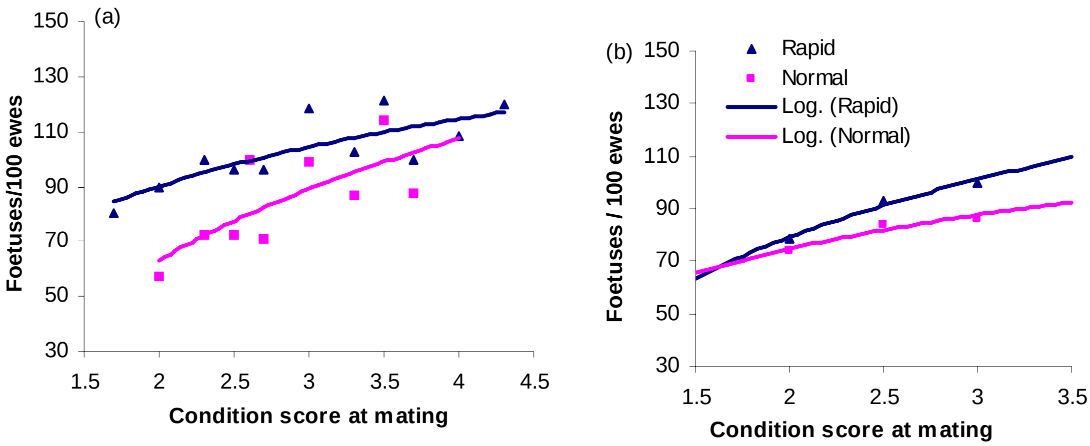

Figure 4. Relationship between number of foetuses at pregnancy scanning and CS at (a) hogget mating and (b) second mating of Merino ewes that followed a normal growth path (pink) or rapid growth path (blue) from weaning to 300 days of age.

Using the equations generated from the curves in Figure 4a and b, at the hogget mating (2005), rapid growth ewes with CS 3.0 would have 104 foetuses/100 ewes and 101 foetuses/100 ewes at their second mating (2006). At the same CS, normal growth ewes would have 88 foetuses/100 ewes at both matings. This means that ewes that grow rapidly from weaning to 300 days of age are likely to have at least 10% more lambs each year at the same condition score as ewes that have grow on a normal post weaning growth path. However, there may be other permanent environmental effects that are also contributing to this difference. In addition, there were not enough ewes within each progeny group to analyse these response curves to determine whether there are between sire differences.

4.1.1.2 Crossbred lamb phenotypes

4.1.1.2.1 Liveweight

Terminal cross lambs from ewes grown on a rapid post weaning growth path were 0.7 to 0.8kg heavier from marking to 280 days of age compared to terminal cross lambs born to ewes raised under a traditional post-weaning growth path (Table 12). This difference was significant from marking to 190 days of age. There was no effect of dam growth path on EMD or c-fat thickness at 280 days of age or postweaning WEC of terminal crossbred lambs. This demonstrates that growth path of the dam does affect phenotypic liveweight, but not EMD, c-fat thickness or postweaning WEC of her offspring. Lambs born in 2006 were heavier at all ages and had higher EMD, cfat thickness, but lower WEC.

Table 12. Mean liveweight (kg±SEM), eye muscle depth (EMD; mm±SEM), c-fat thickness (mm±SEM) and worm egg count (WEC; egg/g±SEM), of terminal crossbred lambs from ewes grown under normal or rapid post weaning growth paths, born in 2005 or 2006 and the level of significance of growth path and year of birth (P).

	Dam growth path			Year of birth		
Age (d)	**Rapid**	**Normal**	**P**	**2005**	**2006**	**P**
0	4.79 ± 0.048	4.43 ± 0.056	0.235	3.82 ± 0.052	5.10 ± 0.054	<0.0001
50	15.4 ± 0.26	14.6 ± 0.30	0.012	12.3 ± 0.29	17.7 ± 0.28	<0.0001
100	26.1 ± 0.29	25.2 ± 0.33	0.004	25.1 ± 0.32	26.2 ± 0.31	<0.001
150	30.9 ± 0.32	30.1 ± 0.35	0.035	29.4 ± 0.34	31.5 ± 0.33	<0.0001
190	32.9 ± 0.35	31.9 ± 0.40	0.012	31.0 ± 0.39	33.7 ± 0.37	<0.0001
235	38.3 ± 0.40	37.6 ± 0.45	ns	37.6 ± 0.44	38.2 ± 0.42	ns
280	41.4 ± 0.41	40.7 ± 0.47	ns	39.9 ± 0.45	42.2 ± 0.43	<0.0001
EMD	27.2 ± 0.21	27.0 ± 0.24	ns	24.0 ± 0.24	30.2 ± 0.23	<0.0001
c-fat	2.82 ± 0.052	2.75 ± 0.060	ns	2.05 ± 0.058	3.52 ± 0.055	<0.0001
WEC	405 ± 1.1	370 ± 1.2	ns	1170 ± 1.1	128 ± 1.1	<0.0001

Merino ram had a significant effect on liveweights of their terminal cross grand lambs from birth to final weighing at 280 days of age (Table 13). This is in agreement with the results observed in SHGEN027 and re-enforces the importance of considering the impact of Merino genes in prime lamb production systems. There was no effect of Poll Dorset ram on liveweight with the exception of liveweight at 235 days of age. This is to be expected as Poll Dorset rams were selected to be of similar liveweight EBVs. Both Merino ram and Poll Dorset ram had significant effects on EMD and c-fat thickness measured with ultrasound scanning. The variation between the Merino rams is only small however, and is unlikely to contribute large changes to carcass fatness and loin size.

There was no interaction between Merino grandsire and growth path of the dam on the lambs' liveweight, EMD, c-fat or post weaning WEC (Table 13).

Table 13. Range in mean liveweight (kg±SEM), eye muscle depth (EMD; mm±SEM), c-fat thickness (mm±SEM) and worm egg count (WEC; egg/g±SEM), of terminal crossbred lambs out of ewes from 13 different Merino rams, the level of significance of merino ram (Mo ram) and Poll Dorset sire (PD) and the significant interaction terms in the analysis.

Age	min	max	Mo ram (P)	PD (P)	Interactions
0	3.39 ± 0.129	4.73 ± 0.144	<0.0001	ns	-
50	12.9 ± 0.64	17.2 ± 0.82	0.003	ns	Mo ram * Year (P=0.011)
100	23.9 ± 0.53	27.9 ± 0.92	<0.0001	ns	Growth * Mo ram (P=0.04); Year * Mo ram (P=0.01) PD ram * Mo ram (P=0.003)
150	28.8 ± 0.59	32.8 ± 0.99	0.004	ns	Growth * Mo ram (P=0.03)
190	30.6 ± 0.65	33.3 ± 1.11	<0.001	ns	Growth * Mo ram (P=0.04); PD ram * Mo ram (P=0.001)
235	36.1 ± 0.73	40.6 ± 1.12	<0.001	0.026	Growth * Mo ram (P=0.01); PD ram * Mo ram (P=0.002)
280	38.7 ± 0.76	44.3 ± 1.16	<0.001	ns	PD ram * Mo ram (P=0.03)
EMD	26.1 ± 0.67	28.3 ± 0.61	0.017	0.003	-
c-fat	2.51 ± 0.163	3.10 ± 0.149	0.009	0.037	-
WEC	354 ± 1.3	468 ± 1.2	ns	0.024	-

4.1.1.2.2 Carcass characteristics

There was no effect of ewe weaner growth path on any of the carcass characteristics of their terminal cross lambs, with the exception of pH 24 hours after slaughter (Table 14). The lambs from normal ewes were 0.02pH units greater than the lambs from ewes grown on a rapid growth path. This is unlikely to have any biological effect and this is supported by the absence of any effect of dam growth path on loin colour, tenderness or glycogen content. Lambs born to ewes from the rapid growth path had 300g heavier CCWT (p<0.1), reflecting the slight difference in liveweight prior to slaughter. There was a significant year effect on all carcass characteristics measured, with the exception of EMW (Table 14), reflecting differences in the finishing systems and age of slaughter between years.

Table 14. Mean cold carcass weight (CCWT; kg±SEM), GR thickness, eye muscle depth (EMD; mm±SEM), c-fat thickness (mm±SEM), loin lightness (L*), redness (a*), pH measured 24h post slaughter (pH_{24}) loin tenderness (SF) and glycogen potential (g/100g tissue) of terminal crossbred lambs from ewes grown under normal or rapid post weaning growth paths, born in 2005 or 2006 and the level of significance of growth path and year of birth (P).

	Dam growth path			Year of birth		
	Rapid	Norm	P	2005	2006	P
CCWT (kg)	21.3 ± 0.21	21.0 ± 0.24	0.096	18.8 ± 0.43	23.4 ± 0.33	<0.0001
GR	13.6 ± 0.29	13.7 ± 0.33	0.792	12.2 ± 0.38	15.0 ± 0.31	<0.0001
Cfat (mm)	4.9 ± 0.15	4.7 ± 0.17	0.197	5.3 ± 0.20	4.3 ± 0.16	<0.0001
EMD (mm)	29.8 ±0.24	29.9 ±0.28	0.558	28.9 ± 0.51	30.9 ± 0.37	0.009
EMW	60.0 ± 0.28	59.9 ± 0.32	0.615	60.3 ± 0.37	59.6 ± 0.30	0.078
L*	33.3 ± 0.15	33.2 ± 0.17	0.432	33.8 ± 0.31	32.7 ± 0.24	0.020
a*	17.8 ± 0.10	17.8 ± 0.11	0.385	17.1 ± 0.21	18.5 ± 0.15	<0.0001
pH_{24}	5.71 ± 0.011	5.73 ± 0.013	0.049	5.68 ± 0.023	5.75 ± 0.017	0.053
SF ()	3.82 ± 0.118	3.90 ± 0.113	0.459	3.15 ± 0.246	4.57 ± 0.182	<0.001
glycogen	0.86 ± 0.016	0.88 ± 0.018	0.238	0.94 ± 0.032	0.81 ± 0.024	0.006

Merino ram had a significant effect on carcass weight, eye muscle width, loin lightness and glycogen potential of their terminal cross grand lambs (Table 15). This is in agreement with the results observed in SHGEN027 and re-enforces the importance of considering the impact of

Merino genes in prime lamb production systems. There was no effect of Merino ram on GR or c-fat thickness, EMD, pH24 or tenderness. Poll Dorset ram had significant effect on c-fat thickness, EMD and EMW, loin redness, pH, glycogen potential and shear force (Table 15). The variation between the Merino rams is only small however, and is unlikely to contribute large changes to carcass quality, however there is a significant impact on carcass weight. The implications for this are discussed in more detail in the SHGEN027 Final Report.

Table 15. Range in mean cold carcass weight (CCWT; kg±SEM), GR thickness, eye muscle depth (EMD; mm±SEM), c-fat thickness (mm±SEM), loin lightness (L*), redness (a*), pH measured 24h post slaughter (pH_{24}) loin tenderness (SF) and glycogen potential (g/100g tissue) of terminal crossbred lambs out of ewes from 13 different Merino rams, the level of significance of merino ram (Mo ram) and Poll Dorset sire (PD) and the covariate and significant interaction terms in the analysis.

		Mo ram			PD ram	Interactions
	Covariate	min	max	P	P	
CCWT	age	20.4 ± 0.51	22.3 ± 0.53	0.001	0.111	-
GR	CCWT	12.4 ± 0.83	14.6 ± 0.79	0.169	0.156	-
Cfat	CCWT	4.4 ± 0.34	5.3 ± 0.42	0.578	0.010	Year * PDram
EMD	CCWT, age	28.8 ± 0.58	31.1 ± 0.62	0.245	<0.001	Growth * Moram
EMW	CCWT	58.2 ± 0.77	62.0 ± 0.68	0.008	0.018	Year * PDram
L*	age	32.5 ± 0.37	34.2 ± 0.41	<0.0001	0.079	-
a*	CCWT, age	17.3 ± 0.20	18.2 ± 0.23	0.058	<0.001	-
pH_{24}	CCWT, age	5.67 ± 0.027	5.77 ± 0.027	0.561	0.338	-
SF	CCWT	3.31 ± 0.307	4.35 ± 0.284	0.209	<0.001	-
Glycogen	age	0.83 ± 0.044	0.94 ± 0.039	0.021	<0.001	-

There were no interactions between growth path of the Merino dams and Merino ram with the exception of EMD. However as there was no effect of Merino ram on EMW this interaction is unlikely to be of biological significance. There were interactions between year of birth and Poll Dorset ram on c-fat thickness and EMW, possibly reflecting differences in finishing systems or mean age of slaughter between years.

4.1.2 Conclusion

A clear divergence in post weaning growth paths between the rapid growth ewes and the normal growth ewes and in the expression of merino genes in both the Merino and terminal cross progeny provides a good model to test the proposed hypotheses.

Post weaning growth path affected post weaning weight, hogget fleece weight and hogget fibre diameter directly reflecting differences in nutrition. Likewise there was a significant difference between Merino rams in their ewe progeny's liveweight, carcass and wool traits and reproduction. However, there were few consistent interactions between growth path and Merino ram, indicating that there would be little re-ranking of these Merino rams ewe progeny when managed under different environments.

Merino ewes that grow rapidly from weaning to 300 days of age have increased reproductive potential compared to those that follow traditional "merino-weaner" growth paths. Growth of Merino ewe weaners affects the number of foetuses conceived, independent of liveweight and condition score at mating. The number of foetuses conceived follows similar curves to that described in the literature for both growth paths; however weaner growth causes the curve to move along the y-axis. Weaner growth path did not affect lamb survival or lamb liveweights and there was no growth path by genotype effect.

All of these results provide an excellent model to assess the impact of environment on the EBVs.

Prime lamb production was influenced by Merino genetics in the terminal cross lambs, but growth path of their dams had little consistent effect on carcass characteristics. There was a slight increase in liveweight and carcass weight, although this difference was small.

4.2 Effect of genotype and weaner growth path on estimated breeding values.

4.2.1.1 Merino progeny

4.2.1.1.1 Liveweight and carcass traits

There was no effect of post weaning growth path on mean progeny group EBVs for WWT, PWWT, HWT, PEMD, or PFAT EBV (P>0.1; Table 16), nor YWT, AWT, PFEC or YFEC EBVs (P>0.1; data not shown).

Table 16. Mean (±SEM) liveweight and live carcass trait EBVs of progeny groups from 13 Merino sires. Weaners were grown under normal or rapid post weaning growth paths. WWT = weaning weight EBV; PWWT = post weaning weight EBV; HWT = hogget weight EBV; PEMD = post weaning eye muscle depth EBV; PFAT = post weaning fat depth EBV.

	WWT (kg)	PWWT (kg)	HWT (kg)	PEMD (mm)	PFAT (mm)
Rapid growth	1.02 ± 0.050	1.84 ± 0.06	2.36 ± 0.07	0.27 ± 0.021	0.04 ± 0.022
Normal growth	1.06 ± 0.033	1.91 ± 0.04	2.37 ± 0.05	0.24 ± 0.014	0.03 ± 0.014
Merino sire					
Ram 1	2.2 ± 0.09	3.1 ± 0.11	4.7 ± 0.12	0.22 ± 0.036	-0.17 ± 0.037
Ram 2	2.2 ± 0.08	4.3 ± 0.10	5.8 ± 0.11	0.20 ± 0.032	0.03 ± 0.033
Ram 3*	0.6 ± 0.11	1.9 ± 0.14	2.0 ± 0.16	0.75 ± 0.047	0.46 ± 0.048
Ram 4*	0.4 ± 0.13	1.2 ± 0.16	1.6 ± 0.18	0.09 ± 0.054	0.08 ± 0.056
Ram 5	1.5 ± 0.08	1.6 ± 0.10	1.4 ± 0.11	-0.04 ± 0.034	-0.04 ± 0.035
Ram 6	0.7 ± 0.08	2.5 ± 0.11	4.0 ± 0.12	0.61 ± 0.035	0.06 ± 0.037
Ram 7	1.6 ± 0.08	1.9 ± 0.10	1.1 ± 0.11	0.42 ± 0.033	-0.01 ± 0.034
Ram 8	0.3 ± 0.08	0.1 ± 0.10	0.6 ± 0.11	0.38 ± 0.032	0.28 ± 0.033
Ram 9*	1.2 ± 0.13	1.5 ± 0.17	2.0 ± 0.18	0.35 ± 0.053	0.00 ± 0.055
Ram 10*	0.1 ± 0.12	1.7 ± 0.15	2.6 ± 0.17	-0.49 ± 0.050	-0.34 ± 0.052
Ram 11*	0.3 ± 0.11	0.4 ± 0.14	0.3 ± 0.16	0.06 ± 0.047	-0.22 ± 0.049
Ram 12*	0.7 ± 0.12	1.7 ± 0.15	2.0 ± 0.17	0.06 ± 0.051	-0.05 ± 0.053
Ram 13*	1.6 ± 0.12	2.4 ± 0.15	2.7 ± 0.17	0.72 ± 0.051	0.35 ± 0.023

There was a significant effect of Merino ram on the mean liveweight and carcass trait EBVs of the progeny groups (P<0.0001; Table 16). The range in mean EBVs between the progeny groups is identical to that which would be predicted from the Merino ram EBVs. The range in Merino ram PWWT EBV was 8.6kg and it would be predicted that their progeny would have a range of 4.3kg PWWT EBV. The observed range between progeny groups was 4.1kg PWWT EBVs. Likewise, there was an 11.3kg range in Merino ram HWT EBVs which resulted in a 5.5kg range in their progeny groups means.

There was no Merino ram by growth path interaction for any of the liveweight or carcass trait EBVs. Mean liveweight and carcass EBVs of the Merino ram progeny groups grown under the rapid growth path were significantly correlated with the mean EBVs of the normal growth path progeny groups (r > 0.9; eg Figure 5a), further demonstrating the robustness of the EBVs to describe the genetic potential of the sheep.

There was a significant correlation between liveweight PWWT EBVs and phenotypic liveweight (Figure 5b. Rapid growth r=0.641; Normal growth r=0.692). Figure 5 shows that the slope of the line is similar between the two growth paths, but there is a shift up the y-axes between the rapid and normal growth paths. The absence of a sire x nutrition interaction indicates that post weaning growth path does not affect the estimation of growth EBVs in Merinos.

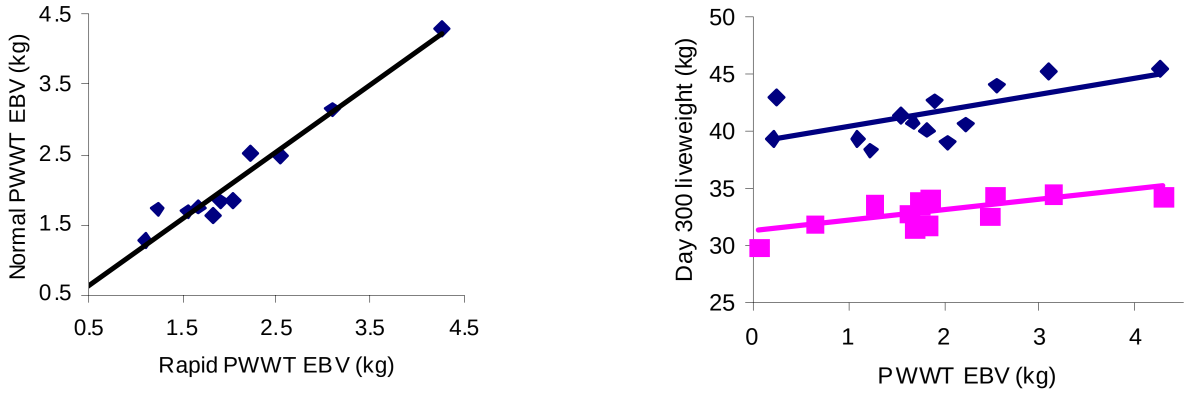

Figure 5. Regression of (a) normal growth path post weaning weight (PWWT) EBVs on rapid growth path PWWT EBVS and (b) mean progeny group 300day liveweights on PWWT EBV of sheep on a rapid (blue diamonds) or normal (pink squares) post weaning growth path.

4.2.1.1.2 Weaner survival

Weaning weight EBVs from October 2005 MGS analysis were used to examine the effect of survival to break of season and sire on WWT EBV. Weaners that survived to the break of season and to hogget shearing had higher WWT EBVs than the weaners that died over summer/autumn or before hogget shearing (Figure 6). There was no interaction between sire and survival on WWT EBV. These results suggests that the progeny with the highest WWT EBVs within sire group are more likely to survive than their half-sibs with lower WWT EBVs and there are no rams (within the 2003-drop) that contradict this trend.

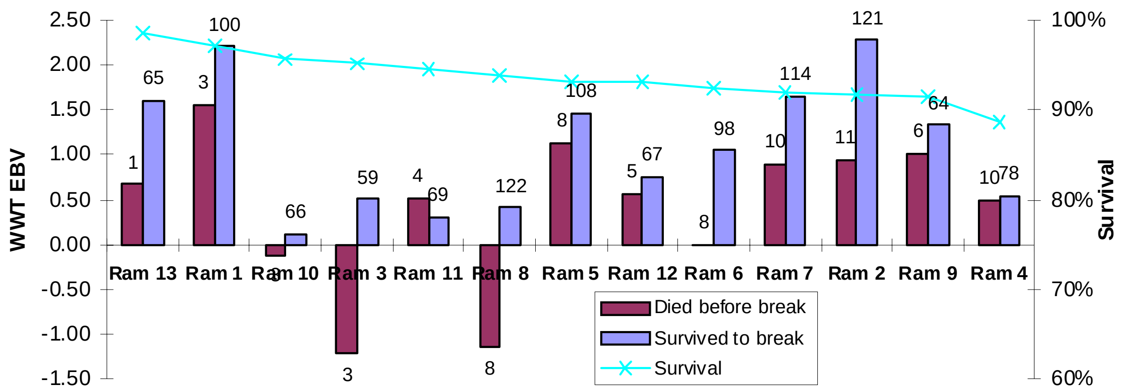

Figure 6. Mean weaning weight EBV and survival and mortality to the break of season of progeny of individual Merino rams. Data labels are the number of progeny from each ram used to calculate average EBV.

There was no relationship between WWT EBV for each ram and the survival of progeny. Figure 6 has been sorted from highest weaner survival to lowest weaner survival but there is not a similar sorting of average WWT EBV. This suggests that using WWT EBVs to select rams for merino weaner survival will not be successful.

4.2.1.1.3 Wool production

Merino ram had a significant effect on mean progeny group HCFW, ACFW, HFD and AFD EBVs (P<0.0001; Table 17), however there was no effect weaner growth path on fleece EBVs, nor was there any interaction between Merino ram and growth path on the fleece EBVs. This is in contrast to the conclusions of Carrick and Van der Werf (2007) who found evidence of GxE for HCFW but not HFD when analysing a much larger dataset. In their analysis environmental variation included many more environmental effects than post weaning nutrition.

There was a significant correlation between mean EBVs from sires' progeny on the Rapid growth path compared to those same sires' progeny on the Normal growth path for HCFW (r = 0.940) and HFD (r = 0.979).

Table 17. Mean (±SEM) fleece characteristic EBVs of progeny groups from 13 Merino sires. Weaners were grown under normal or rapid post weaning growth paths. HCFW – hogget clean fleece weight EBV; HFD – hogget fibre diameter.

	HCFW (%)	HFD (um)
Rapid growth	0.10 ± 0.98	-0.36 ± 0.026
Normal growth	0.09 ± 0.64	-0.36 ± 0.017
Merino sire		
Ram 1	-0.09 ± 0.017	-0.78 ± 0.046
Ram 2	-0.10 ± 0.015	-0.53 ± 0.040
Ram 3*	0.25 ± 0.022	-0.39 ± 0.059
Ram 4*	0.27 ± 0.026	-0.37 ± 0.068
Ram 5	0.06 ± 0.016	-0.35 ± 0.043
Ram 6	0.27 ± 0.017	0.40 ± 0.045
Ram 7	0.09 ± 0.016	-0.31 ± 0.042
Ram 8	-0.02 ± 0.015	-1.25 ± 0.041
Ram 9*	0.23 ± 0.025	-0.70 ± 0.068
Ram 10*	0.12 ± 0.024	-0.13 ± 0.063
Ram 11*	0.04 ± 0.022	-0.51 ± 0.059
Ram 12*	0.40 ± 0.024	0.040 ± 0.064
Ram 13*	-0.03 ± 0.024	0.20 ± 0.064

Figure 7 illustrates the relationship between mean progeny EBV and the phenotypic expression of individual wool traits on the two different growth paths. For both HFD and HCFW there was a significant correlation between EBVs for the wool traits and the phenotypic expression of the wool traits for both growth paths. The slopes of the lines are similar but the rapid growth path moves the intercept up the y-axis reflecting the increase in the phenotypic expression of the wool traits as a result of increased nutrition.

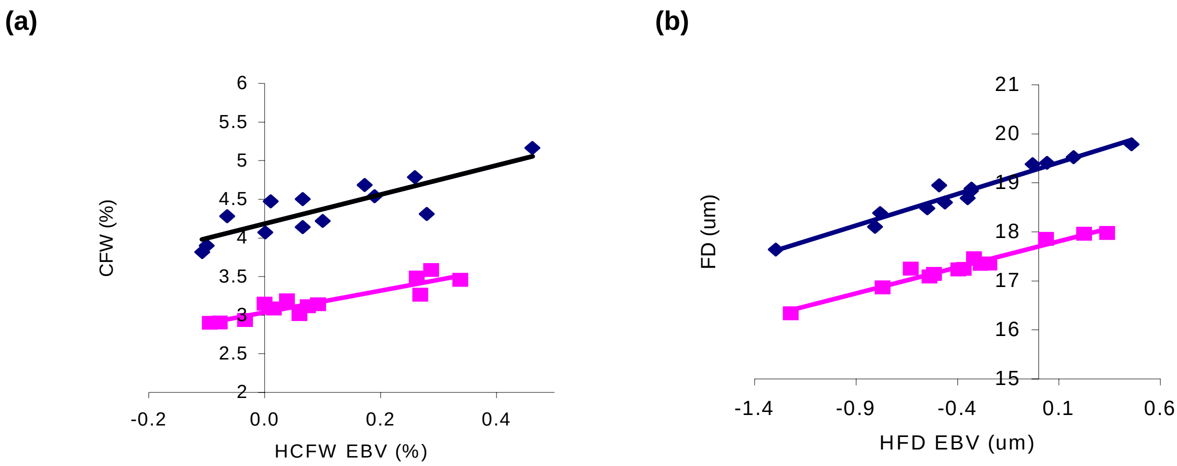

Figure 7. Regression of mean progeny group (a) hogget clean fleece weight and (b) fibre diameter (FD) on mean progeny group post weaning weight (PWWT) and fibre diameter (HFD) EBV of sheep on a rapid (blue diamonds) or normal (pink squares) post weaning growth path.

There was no genotype by environment interaction on progeny EBV for any of the analysed wool traits. The absence of a sire x nutrition interaction indicates that post weaning growth path does not affect wool EBVs and EBVs can be confidently used to compare progeny that have undergone different post-weaning growth paths.

4.2.1.1.4 Reproduction

Merino ram had a significant effect on NLW EBV (P<0.0001; Table 18) with 13% more lambs being weaned from the highest ranking ram compared to the lowest ranking ram. There was no effect of weaner growth path on the EBV which is not surprising as no progeny data was included in the October 2005 analysis and so no phenotypic growth path data was used to calculate the EBVs. EBVs were re-analysed in July 2007 by Sheep Genetics Australia using data collected on the number of lambs weaned in 2005 and 2006 in the Merino analysis. Merino ram had a significant effect on NLW EBV (P<0.0001) and there was a significant growth path effect (P<0.0001; Table 17).

Table 18. Mean (±SEM) number of lambs weaned EBVs (NLW) of progeny groups from 13 Merino sires calculated in October 2005 and July 2007. Weaners were grown under normal or rapid post weaning growth paths.

	NLW (%) – Oct 2005	NLW (%) – July 2007
Rapid growth	2.2 ± 0.12	2.9 ± 0.19
Normal growth	2.2 ± 0.08	1.4 ± 0.20
Merino sire		
Ram 1	4.6 ± 0.20	5.8 ± 0.48
Ram 2	5.8 ± 0.18	5.7 ± 0.41
Ram 3*	3.3 ± 0.26	2.1 ± 0.52
Ram 4*	-0.5 ± 0.31	6.8 ± 0.61
Ram 5	3.0 ± 0.19	-0.4 ± 0.42
Ram 6	7.6 ± 0.20	4.2 ± 0.44
Ram 7	-0.1 ± 0.19	5.9 ± 0.40
Ram 8	3.3 ± 0.18	3.1 ± 0.41
Ram 9*	1.4 ± 0.30	-2.6 ± 0.59
Ram 10*	-1.1 ± 0.28	-0.3 ± 0.55
Ram 11*	-5.5 ± 0.26	-3.5 ± 0.49
Ram 12*	3.5 ± 0.29	-1.3 ± 0.57
Ram 13*	3.6 ± 0.29	2.7 ± 0.53

Relationship between Merino ram NLW EBV and ewe progeny reproductive performance. There were poor relationships between Merino ram EBVs and the reproductive performance measurements of their ewe progeny from the two growth paths (Table 19). When data from both growth paths were combined there was still no relationship between phenotypic measures of reproductive performance and sire NLW EBVs (Table 19). Accuracy of the EBVs ranged between 29 and 79%, however the rams NLW EBVs were not a good indicator of the reproductive ability of their ewe progeny in this trial. If the six rams with an accuracy of less than 50% are not included in the regression analysis, only the relationship between NLW EBV and foetal survival of progeny from ewes in the rapid growth group reach a significant correlation (r=0.776; P=0.04).

Table 19. Correlation coefficient (R) between Merino ram NLW EBV and ewe progeny conception rate, survival of scanned foetuses to weaning (survival) and lambs weaned (NLW). Ewes were grown under normal or rapid post weaning growth paths.

	Conception	Survival	NLW
Normal growth path	0.167	0.319	0.266
Rapid growth path	0.046	0.519	0.406
Combined growth paths	0.004	0.455	0.395

EBVs of the Merinos were calculated by Merino Genetic Services (Sheep Genetics) in October 2005 using data collected on the individual progeny and all other related data. This is the type of information that would be used to select rams for breeding programs and should be good indicators of how the rams perform. These EBVs were poor predictors of actual reproductive performance of their daughters. There was no improvement in the relationship between EBVs and actual reproductive performance even when direct reproductive ability of the daughters was included (July 2007 Merino analysis). In fact there was bias between environments in that ewes that underwent the rapid post weaning growth path had higher NLW EBVs than ewes that were grown on a normal post weaning growth path.

In September 2007, the Sheep Genetics Technical Committee has undertaken an intensive review of the analysis method used to calculate breeding values for number of lambs born and NLW and identified that there was some bias in the analysis of reproduction records from ewes which have failed to raise a lamb which are often not included in the analysis. In order to solve this issue, the Sheep Genetics Technical Committee has recommended changes to the calculation of reproduction breeding values. These changes may improve the relationship between breeding values and observed reproductive performance.

4.2.1.2 Crossbred lamb liveweight and carcass EBVs

Post weaning growth path of the dams of terminal crossbred lambs did not affect liveweight EBVs of the terminal crossbred lambs (Table 20). Growth EBVs were negative as these EBVs were calculated in the terminal analysis and therefore the crossbred lambs performance is less than the purebred terminal performance. Merino ram had a significant effect on BWT, WWT, PWWT, PFAT, PEMD and WFEC of the terminal crossbred lambs ($P<0.0001$; Table 20) indicating that Merino genes do affect the liveweights of their terminal crossbred grand lambs. There is approximately 2kg range between Merino rams in WWT and PWWT EBVs which could have a considerable impact on the production of terminal cross lambs. The range in EMD was and PFAT was less than 1mm and unlikely to have an economic impact. There were not any significant interactions between Merino ram and Merino weaner growth path on any of the terminal crossbred lamb EBVs analysed.

Table 20. Mean (±SEM) liveweight and live carcass trait EBVs of terminal crossbred lamb progeny groups from 13 maternal Merino grandsires. The prime lamb dams were grown under normal or rapid post weaning growth paths. BWT = birth weight EBV; WWT = weaning weight EBV; PWWT = post weaning weight EBV; PEMD = post weaning eye muscle depth EBV; PFAT = post weaning fat depth EBV.

	BWT (kg)	WWT (kg)	PWWT (kg)	PEMD (mm)	PFAT (mm)
Rapid growth	-0.12 ± 0.005	-2.9 ± 0.07	-5.8 ± 0.13	-0.57 ± 0.046	-2.0 ± 0.03
Normal growth	-0.14 ± 0.007	-3.0 ± 0.08	-5.8 ± 0.15	-0.64 ± 0.053	-2.1 ± 0.04
Merino sire					
Ram 1	-0.12 ± 0.015	-3.3 ± 0.19	-6.4 ± 0.35	-0.75 ± 0.127	-2.3 ± 0.09
Ram 2	-0.08 ± 0.013	-2.5 ± 0.18	-4.7 ± 0.31	-1.00 ± 0.112	-1.9 ± 0.08
Ram 3*	-0.13 ± 0.015	-3.3 ± 0.20	-6.2 ± 0.36	-0.33 ± 0.130	-2.0 ± 0.09
Ram 4*	-0.16 ± 0.016	-2.5 ± 0.22	-4.7 ± 0.39	-0.48 ± 0.138	-1.9 ± 0.10
Ram 5	-0.20 ± 0.015	-3.0 ± 0.19	-6.3 ± 0.35	-0.47 ± 0.125	-2.1 ± 0.09
Ram 6	-0.08 ± 0.014	-3.3 ± 0.19	-6.0 ± 0.33	-0.55 ± 0.118	-2.0 ± 0.08
Ram 7	-0.10 ± 0.010	-4.0 ± 0.13	-6.8 ± 0.24	-0.61 ± 0.084	-2.0 ± 0.06
Ram 8	-0.11 ± 0.014	-3.3 ± 0.18	-7.0 ± 0.32	-0.51 ± 0.116	-2.0 ± 0.08
Ram 9*	-0.12 ± 0.016	-3.3 ± 0.21	-5.7 ± 0.39	-0.46 ± 0.138	-2.1 ± 0.10
Ram 10*	-0.14 ± 0.017	-2.9 ± 0.22	-5.3 ± 0.40	-0.96 ± 0.143	-2.7 ± 0.10
Ram 11*	-0.12 ± 0.016	-3.2 ± 0.21	-6.2 ± 0.38	-0.82 ± 0.135	-2.4 ± 0.10
Ram 12*	-0.11 ± 0.018	-2.2 ± 0.24	-5.3 ± 0.42	-0.71 ± 0.151	-2.2 ± 0.10
Ram 13*	-0.13 ± 0.016	-2.1 ± 0.21	-4.5 ± 0.38	-0.28 ± 0.136	-1.9 ± 0.10

4.2.2 Conclusion

EBVs for Merino PWWT, HCWT and HFD will be comparable regardless of the post weaning growth path that the Merino lambs follow. There was no difference in EBVs of progeny from the same sire group, regardless of the weaner growth path. This study has shown that for a sample of Merinos, the effects of different progeny growth paths were successfully removed in the production of EBVs. This project provides support for the ability of EBVs to remove the effect of environment from the phenotypic measurements of sheep and allow comparisons between sheep regardless of the environment in which they were raised. The only exception to this is NLW.

To maximise reproductive performance of Merinos ewes it is necessary to utilise both genetics and nutrition management techniques. The results from this experiment have shown that post weaning nutrition has a consistent effect on conception rate with 10% more lambs conceived per year in the rapid growth ewes and fewer dry ewes at first mating. Merino ram also influenced conception rate as well as lamb survival but did not affect the ability of ewes to get pregnant. There was no interaction between growth path and Merino sire in most situations. It is therefore recommended that to maximise lamb production through reproductive performance it is necessary to identify rams that have high number of lambs weaned and then feed the ewes to continue to grow until their first mating at 18 months. However the ability to identify rams with high reproductive potential is difficult as in this trial Merino ram EBVs were not a good indicator of phenotypic measures of reproduction.

5 Success in Achieving Objectives

5.1 Influence of environment on expression of Merino genes in prime lamb production systems.

This project has identified that ewe weaner growth path is unlikely to impact on the expression of Merino genes in prime lamb production systems, with the possible exception of number of lambs weaned. There was only a small GxE interaction in the expression of Merino hogget wool production, which is potentially important if prime lamb producers are breeding their own replacement ewes in which hogget wool production is an important contributor to the prime lamb production system. However in adult merino ewes there was no GxE effect on wool production. Merino genes will be expressed comparably in terminal cross lambs regardless of merino ewe weaner growth path. Furthermore, GxE does not change the phenotypic ranking of progeny groups that have undergone dissimilar weaner growth paths.

5.2 Increase lamb production through maximising genetic potential of Merino genes.

Use of post weaning growth path is unlikely to be a suitable management technique to maximise genetic potential of Merino genes.

5.3 Increase lamb production through maximising reproductive performance of Merino ewes.

Increasing post weaning growth paths of Merino ewes could possibly contribute an extra 10% more lambs per year per flock. This project is the first to report this possibility for prime lamb production systems. This was an unexpected outcome as the original hypothesis was to maximise reproductive performance of Merino ewes by demonstrating the feasibility of mating Merino ewes as lambs to increase the potential number of prime lambs through increased mating opportunities. This strategy was unsuccessful but we were successful in maximising reproductive performance of Merino ewes by increasing the number of lambs weaned per mating.

6 Impact on Meat and Livestock Industry – now & in five years time

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, carcass weight and some aspects of meat quality. Prime lamb producers should be encouraged to select Merinos that have high growth potential and carcass traits as this will be expressed in their prime lambs.

This project will also have an immediate impact by demonstrating that EBVs are able to remove phenotypic variation that occurs as a result of different weaner growth paths and that EBVs can be used reliably to compare and predict liveweight and carcass attributes of Merino genes in prime lamb production systems. Prime lamb producers should have confidence that by selecting rams based on liveweight and carcass EBVs, their progeny will perform as the EBVs predict.

In five years time this project may impact prime lamb production through improvement in Merino ewe post weaning nutrition. This will increase the number of Merino ewes available for reproduction through increased Merino weaner survival as well as increasing the number of lambs weaned.

This project has the potential to impact on future prime lamb production by providing incentive to further improve the accuracy of NLW EBVs. This project demonstrated that NLW EBV is a poor predictor of actual reproductive performance and NLW EBV was not able to remove environmental effects of post weaning nutrition on reproductive rate. Further research is required to either improve the accuracy of NLW EBVs or change the calculation of NLW EBV.

7 Conclusions and Recommendations

EBVs for Merino PWWT, HCWT and HFD were comparable regardless of the post weaning growth path that the Merino weaners followed. The effects of different progeny growth paths were successfully removed in the production of EBVs and prime lamb producers can be confident that EBVs can be used to compare progeny that have undergone different post-weaning growth paths.

To maximise reproductive performance of Merinos ewes it is necessary to utilise both genetics and nutrition management techniques. Post weaning nutrition had a consistent effect on conception rate with 10% more lambs conceived per year in the rapid growth ewes and fewer dry ewes at first mating. Merino ram also influenced conception rate as well as lamb survival but there was no interaction between growth path and Merino sire in most situations. It is recommended that to maximise lamb production through reproductive performance it is necessary to identify rams that have high number of lambs weaned and then feed the ewes to continue to grow until their first mating at 18 months. An economic analysis of this has not been undertaken. Further information on the lifetime reproductive performance of the rapid and normal growth ewes is possible as these ewes have been included in the Struan Research Centre Information Nucleus Flock as part of the CRC for Sheep Industry Innovation.

The ability to identify rams with high reproductive potential is difficult as in this trial Merino ram EBVs were not a good indicator of phenotypic measures of reproduction. It is necessary to improve accuracy of NLW EBVs, although recent changes made to the calculation of reproduction breeding values by Sheep Genetics. These changes may improve the relationship between reproductive breeding values and observed reproductive performance.

Seasonal conditions had an impact on lamb survival in this trial. It was suggested that given the accumulated knowledge on the causes of lamb losses and the sheep industry's exposure to criticism of its low lamb survival rates, the research community should be applying some of the knowledge it has acquired on its research farms. However, as research farms are also run as commercial entities it will be necessary to have appropriate drought feeding contingency in research project funding.

The biological mechanisms underlying the impact of post weaning nutrition on ewe lambs are unknown. Whether the effects seen in this work are simply limited to ME intake or protein/energy ratio is unknown and warrants further work and whether similar responses occur in crossbred ewes lambs is unknown and would also benefit from further investigation.

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9 Appendices

9.1 Appendix 1. Number of weaners allocated to treatments from each Merino ram and number of terminal cross carcasses.

Growth path	Ewe weaners		Wether weaners		Terminal lamb
	Rapid	Normal	Rapid	Normal	carcass
Ram 1	22	23	29	28	41
Ram 2	31	31	35	34	78
Ram 3	20	19		48	45
Ram 4	15	13		34	31
Ram 5	29	31	24	32	48
Ram 6	26	28	26	26	63
Ram 7	31	33	21	39	63
Ram 8	31	32	33	33	63
Ram 9	15	15		39	36
Ram 10	18	16		35	29
Ram 11	22	21		30	36
Ram 12	17	15		40	28
Ram 13	18	19		28	43
Total	295	296	168	446	604

9.2 Appendix 2. Publications and communications

9.2.1 General

1. March 2004 – Re-shaping Merinos with management and genetics. Struan Research Centre Field Day.
2. MLA Prograzier – Spring 2006: Impact of Merino weaner growth path on ewe fertility and fecundity.
3. Report to MLA – August 2006. Does feeding weaners well after weaning improve lamb survival?
4. MLA Prograzier – Autumn 2007: Merino weaner survival.
5. 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.

9.2.2 Scientific

Hocking Edwards, J.E. and Starbuck, T.M. 2006. Growth from weaning to one year of age affects maiden ewe fertility. *Proc. Aust. Soc. Anim. Prod*. **26**: Short communication 79.

Hocking Edwards, J.E. and Starbuck, T.M. Liveweight. 2007. Liveweight and Wool Production Estimated Breeding values are not affected by Post Weaning growth path. *Proc. Assoc. Advmt. Anim. Breed. Genet*. **17**: 252-255.

9.2.3 Papers in preparation.

Hocking Edwards, J.E., Starbuck, T.M. and Gould, R.M. Post-weaning nutrition affects maternal productivity of Merino ewes. *Aust. J. Exp. Agric.*

Hocking Edwards, J.E., Gould, R.M. and Copping, K.J. Strategies to improve merino weaner survival. *Proc. Aust. Soc. Anim. Prod*. 4 page paper.