On farm

Management systems for Border Leicester – Merino ewes carrying the Booroola gene

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FINAL REPORT DAS 27

Abstract

Why was the work done

At the commencement of this project no highly fecund genotypes were available to prime lamb producers despite analyses showing fecundity to be a major factor limiting prime lamb profitability. DAS 27 developed the Booroola Leicester to the stage where prolific Booroola crossbreds are now being used in significant numbers for prime lamb production in South Australia.

What benefits will arise from the work

Practical evaluations on farmers properties throughout south eastern Australia have shown that Booroola crossbred properly managed will return $6-10 more per ewe than normal crossbred ewes run under the same conditions.

Booroola Leicester rams and Booroola crossbreds are available in the south east of South Australia. For more information contact Colin Earl at Struan Research Centre (phone 087 647419).

DAS 27 was funded to provide Australian Prime Lamb Producers with a highly fecund prime lamb mother, and advice on how they could best be managed. The Booroola Leicester is now available in significant numbers and Booroola crossbreds are a feature of first cross ewe sales in South Australia. A management booklet outlining how they are best managed is available and many producers in South Eastern Australia are running significant number very profitably. Their movement into the eastern states is expected over the next few years.

FINAL REPORT DAS 27

Executive Summary

- **Why the work was done?**

DAS 27 was funded to provide Australian Prime Lamb Producers with a highly fecund prime lamb mother and advice on how they could best be managed.

- **What was achieved?**

DAS 27 has taken the number of Booroola Leicesters in South Australia from 2 to over 1000. Over 500 Booroola Leicester rams have been made available to first cross ewe breeders and significant numbers of Booroola crossbreds are now appearing in first cross ewe sales. For instance 3000 Booroola crossbreds are listed for the 1995 first cross ewe sale in Naracoorte, a sale in which Booroola crossbreds achieved the highest price in 1994. Booroola crossbreds are performing profitability on many properties in Victoria and South Australia assuring their continued growth over the next few years.

A booklet detailing a management system for Booroola crossbreds has been written and posted to over 60% of prime lamb producers in South Australia.

Demonstration sites have been run for over 3 years on 7 properties in NSW, Victoria and South Australia. Field days have been held on these sites and uptake has occurred around most of these sites.

Booroola Leicester ewes have been sold from the Struan flock and at least 5 breeders of Booroola Leicesters are established in South Australia. There is a need for more breeding flocks to be established in the eastern states.

- **When and how can the industry benefit from the work?**

The industry is ready to capitalise on the benefits of the Booroola Leicester. The rate of uptake of them will be slow but steady. Any change in genotype in livestock production is necessarily slow, firstly because of the rate of multiplication of the new genotype and secondly because of the conservative nature of producers. However the capture of 10% of the prime lamb mother market in South Australia over the last 5 years has been encouraging. A similar rate of increase in South Australia is likely to occur up to about the 30% level.

To increase the rate of uptake in the eastern states it will be necessary to set up more demonstration sites in Victoria and NSW. This will be necessary because producers seem to need to see something working successfully before they will try it. All the written publicity you can afford does not seem to have the effect of one good demonstration.

- **Who can benefit from the results?**

The principal beneficiaries of this research will be first cross ewe breeders and prime lamb producers. First cross ewe breeders are likely to achieve a slightly higher price for their ewe lambs for a few years as numbers are increasing. Prime lamb producers using Booroola crossbreds will be more profitable than those using Border Leicester crosses. The prime lamb industry as a whole will be more efficient and able to better compete with other prime lamb producing countries.

FINAL REPORT DAS 27
Main Research Project

1. Background and Industry Context

DAS 27 combined two project applications submitted by the South Australian Department of Agriculture into one project titled "Commercial release of Border Leicester rams homozygous for the Booroola gene and development of management systems for their first cross ewe progeny". This project was funded as a continuation of the Corporation funded projects DAS 019 and DAS 020. These two projects had made significant progress towards development of a flock of sheep homozygous for the Booroola gene and answering some of the management problems associated with highly fecund sheep. Considerable further development however was required before the industry could fully capitalise on this work.

At the commencement of DAS 27 no highly fecund genotypes were available to prime lamb producers in Australia. This was despite analyses showing that fecundity was the major limiting factor of prime lamb profitability. Producers were conditioned to accepting relatively low lambing percentages and not keen to embrace highly fecund genotypes. The task of DAS 27 was firstly to supply highly fecund genotypes and secondly to convince producers of their profitability.

2. Project Objectives

(i) To maintain for the life of the project, a selection program for the production and release of Border Leicesters homozygous for the Booroola gene that also have production characteristics required by commercial prime lamb producers, through the involvement of a breeders' group to oversee breeding direction, at both Armidale and Struan.

(ii) By December 1995, to produce, evaluate and promote the use of first-cross ewes carrying the Booroola fecundity gene as prime lamb dams through at least five on-farm validation trials in Victoria and South Australia over three annual matings to December 1995.

(iii) By December 1995, to significantly reduce the number of first-cross high fecundity ewes bearing quadruplet or quintuplet lambs by restricting nutritional plane before mating, without seriously depressing smaller litter sizes.

(iv) By December 1994, to significantly increase lamb survival in prolific ewes by cost-effective nutritional manipulation of maternal reserves, placental function and foetal development.

3. Detailed Methodology

(i) Breeding Border Leicester rams homozygous for the Booroola gene

The process of breeding homozygous rams was based on identifying homozygous rams by progeny testing. Each ram under test was mated to 50 merino ewes and the ovulation rate of the female progeny counted after stimulation with 400iu of PMSG. These rams considered to be homozygous were first used in the Struan breeding flock and then returned to Armidale to be used in the Armidale flock. The continued use of proven homozygous rams in the flock was the means by which the gene frequency in the Struan flock was increased. In the Armidale flock progeny testing of ewes was also carried out to increase the gene frequency at a faster rate.

The second major objective apart from achieving homozygosity at Struan has been to improve growth rate to weaning. Those rams selected for progeny testing have been those which are structurally sound and have the highest corrected growth rate performance.

The original plan to transfer the gene to industry was by the release of homozygous semen to Border Leicester breeders who would then follow the same process of breeding up as in the Struan and Armidale flocks. It was soon realised that this was likely to be a too expensive and unattractive pathway for producers to follow. A decision was therefore made to begin to selling gene carrying Border Leicester ewes to interested producers so that they could begin breeding their flocks from ewes with a high probability of being homozygous.

(ii) **Demonstration Sites**

To promote the use of Booroola crossbreds it was planned to set up 5 demonstration sites, 3 in Victoria and 2 in South Australia. On these sites a minimum of 100 Booroola crossbreds were compared with 100 normal crossbreds and differences in productivity recorded. Field days were to be held at these sites to promote the use of Booroola crossbreds in areas surrounding the demonstration sites.

(iii) **Controlling litter size in Booroola crossbreds**

Litter sizes of 4 or more are a potential problem with Booroola crossbreds. Litter sizes of this magnitude put the ewe at risk from pregnancy toxaemia and in many cases all of the lambs die. To try and control litter size the effects of nutrition premating were examined to determine the extent litter size could be controlled through nutrition.

(iv) **Management of Booroola Crossbreds**

In this section of the work various different rates and types of supplementation were examined to determine a management strategy for Booroola crossbreds under a range of environmental conditions. The effects of varying nutrition at different stages of pregnancy were also examined in a Ph D thesis by Tania Debarro. The trial designs and their implications will be detailed in the results section.

4. Results and Discussion

Breeding Border Leicester Rams Homozygous for the Booroola Gene

(i) At the commencement of DAS 27 2, 7/8 Border Leicester rams homozygous for the Booroola gene had been identified. The task of DAS 27 was to generate a flock of ewes carrying a high percentage of the Booroola gene. The steps involved were to breed those two rams to Border Leicester ewes to produce heterozygotes and then mate these heterozygotes to a second group of identified homozygotes to increase the Booroola gene frequency in the flock. Potentially homozygote rams bred in the Armidale flock were transferred to Struan and progeny tested. Homozygote rams were then used at Struan and returned to Armidale for use in their flock. Different strategies of breeding up have been followed by Armidale and Struan. At Armidale ewes with a high probability of being homozygous were identified by repeated endoscopy. These ewes were then put through embryo transfer programs to increase the flock size and retain a high degree of homozygosity. At Struan the breeding up program has relied on only using homozygous sires and the true genotype of the females has not been determined. This has retained a greater genetic diversity at the expense of homozygosity in the Struan flock.

An advisory committee was active in the first few years of the project but have not met recently. They decided on the name of Booroola Leicester for this breed of sheep and they have been registered as an appendix breed of the AAABS. The advisory committee suggested that sheep from the project be made available to breeders by public auction. Two very successful sales have been held at Struan. In the first in 1993, 110 rams were sold at an average price of $526. In 1994, 110 rams were sold at an average price of $526. In 1994, 110 rams were sold at Struan at an average price of $330. Forty Booroola Leicester ewes were also sold at an average price of $270. A further 50 rams were sold in Wagga at an average price of $330. The Struan flock now contains 400 Booroola Leicester ewes and will continue to supply rams until at least 1997.

(ii) **Transfer of the breeding program to industry**

In 1997 or 1998 the flock will be sold to private producers. Six private breeders of Booroola Leicester already are operating in South Australia, and so the future of the breed in South Australia seems assured.

The only problem with the future of the breed is assurance that stud rams used are homozygote. To ensure this it is likely that the Primary Industries South Australia will continue to do progeny testing on a fee for service basis.

(iii) **Demonstration sites**

Over the course of DAS 27, demonstration sites have operated at Oberon in NSW, Leongatha, Rutherglen, Hamilton and Heywood in Victoria and Mount Gambier and Victor Harbour in South Australia. On these sites a minimum of 100 Booroola crossbreds were compared with a similar number of crossbreds selected by the producer. The comparisons were conducted in a manner designed to cause minimum disruption to the farmers normal operation while still providing useful information on the performance of Booroola crossbreds in that district. Where possible the two groups of ewes were mated together and run together up until lambing. Lambing always occurred separately so that the number of lambs produced from each group could be determined. After lambing, the two groups were sometimes combined and in other cases not. The major end point we were concerned about was the percentages of lambs sold from each group and the producers assessment of their performance under his management conditions.

SITES

PARAWA - 1993

	Booroola		Control	
Age at mating	Scan %	Marking%	Scan %	Marking%
1.5yrs	161	130	117	100

LAMB RETURNS

Booroola	130 lambs at $36.15 = $4,700 or $47.00/ewe
Control	100 lambs at $39.56 = $3,956 or $39.56/ewe

1994	Booroola Marking %	Control Marking %
	157	127

LAMB RETURNS	Booroola	Control
	$53.25/ewe	$44.64/ewe

A field day was held in 1993 at the Parawa site. A follow up talk was held with the local lamb group. One local producer has been a big purchaser of Booroola Leicester rams to breed his own replacement ewes.

HEYWOOD

		Booroola		Control	
	Age of Mating	Scan %	Marking%	Scan%	Marking%
1993	10 mths	157	94	93	77

	Age of Mating	Booroola Marking %	Control Marking %
1994	1.5 yrs	124	97

This trial is continuing in 1995. A field day was held at the site in 1993 and the results from this site have been keenly watched by local prime lamb producers. The owners of this site have purchased a further 600 Booroola crossbreds and another local purchased several hundred Booroola crossbreds at the Naracoorte first cross ewe sale.

KONGORONG

	Age of Mating	Booroola Marking %	Control Marking %
1993	1 yr	120	92
1994	2 yrs	145	120
1995	3 yrs	182	135

Two field days have been held at this site in 1994 and 1995. This site will continue in conjunction with the improved pasture productivity trials run from the Hamilton Pasture Productivity trials. The objective is to demonstrate the most profitable prime lamb production system using a prolific genotype coupled with highly productive pastures.

RUTHERGLEN

In the first year at Rutherglen (1992) the Booroola crosses and Riverina crossbred ewes were mated at 1.5 yrs of age.

Marking %	
Booroola	Riverina
118	98

In the second year a detailed financial analyses of the two ewe types was conducted.

	Booroola	Riverina
Ewe Wool Returns	$1093.66	$1013.58
Lamb wool	$153.80	$67.13

Lamb Returns
126 @ $36.91 = $4,650.13 99 @ $35.09 = $3,473.72

Gross Income = $5,897.59 $4,554.43

Difference = $1,343.16

This represents an increase of $13.43 per ewe mated in favour of the Booroola crossbred ewes.

A field day was held at Rutherglen in 1992.

LEONGATHA

Booroola Marking %	Normal Marking %
138	93
183	163

Producers from the Leongatha region were significant purchasers of Booroola crossbreds at the 1995 first cross ewe sale in Naracoorte. This supports our belief that the demonstration site concept is a good way of influencing management decision making.

(iv) Controlling litter size in Booroola Crossbreds

Introduction

A potential problem in using Booroola crossbreds is the proportion of ewes bearing quads and quins. Under normal management, these ewes may make up 10% of the flock. Ewes bearing quads and quins are at much greater risk to pregnancy toxaemia and the survival rates are unacceptably low. The small amount of literature on this topic indicates that the ovulation rates of Booroola crossbreds are responsive to the level of nutrition prior to mating (King 1986, Montgomery et al 1983). The work of Montgomery et al (1983), suggests that the ovulation rate may decrease by .054 for each kilogram decrease in liveweight at mating. In merinos carrying the Booroola gene it was also found that the premating level of nutrition markedly affected ovulation rate and litter size (Kleeman et al 1987). The benefits of a better understanding of the nutrition and the reproductive interactions in Booroola crossbreds is mainly directed toward reducing ewe and lamb losses rather than improving lambing percentages. In this experiment we will investigate the practical implications of controlling nutrition and liveweight prior to joining on ovulation rate, litter size and overall flock productivity.

Aims

1. To reduce the number of quad and quin bearing ewes by nutritional manipulation at mating.

2. To examine the effects of nutritional manipulation at mating on lamb production and growth.

Null Hypothesis

1. The level of nutrition at mating has no effect on litter size of Booroola crossbreds.

2. The level of nutrition at mating has no effect on total lamb production and growth.

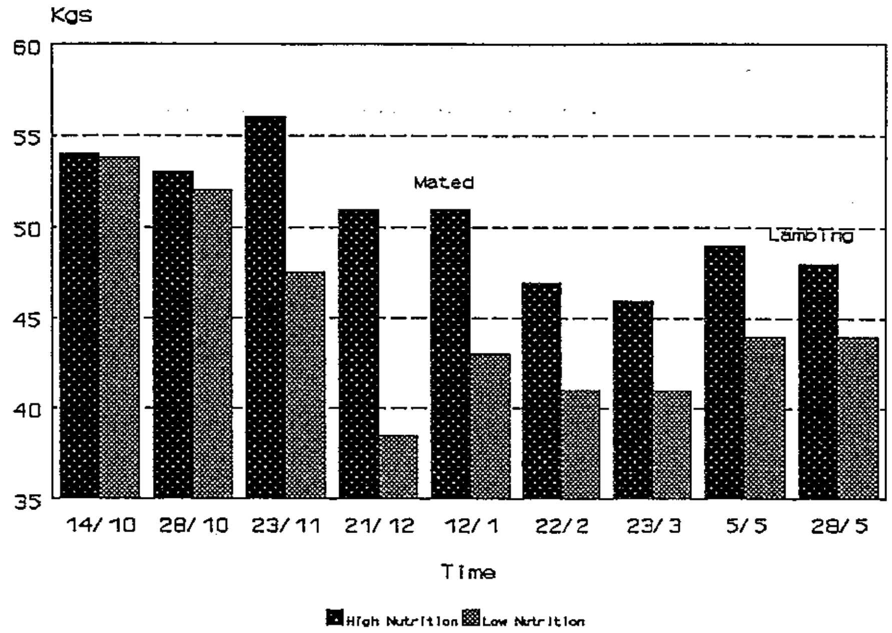
Materials and Methods

Location - This experiment will be conducted using the animals and staff at Struan Research Centre.

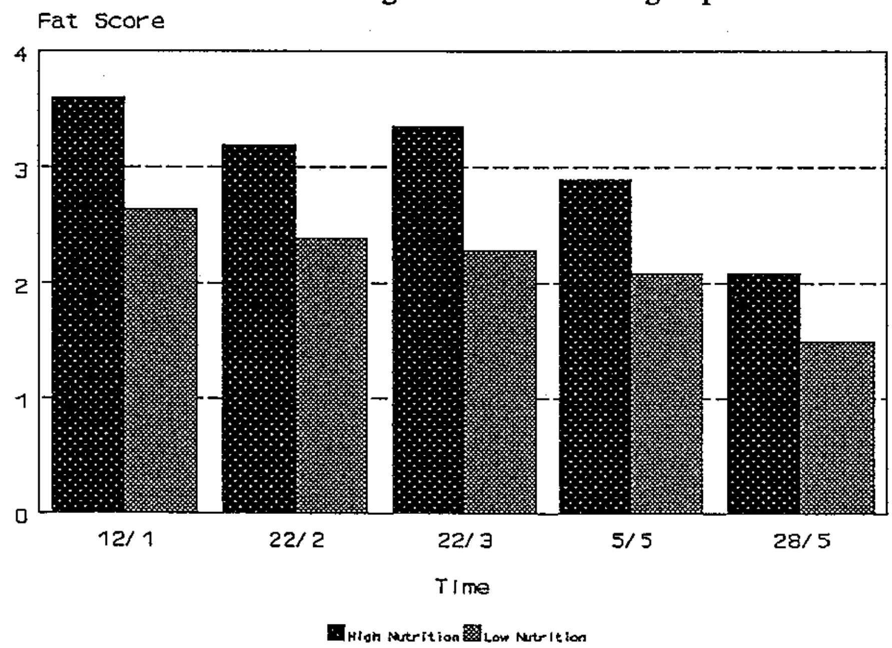
Design - Two hundred and seventy Booroola crossbreds will be divided into two treatment groups on the basis of liveweight 10 weeks prior to mating on the 7/1/93.

A group of Booroola crossbred ewes were divided into a high and low nutrition group prior to mating resulting in an 8kg difference in liveweight at the commencement of mating. Over mating the ewes were run together as one group and ovulation rates over mating recorded. Productivity records were recorded for each group and are presented below.

Liveweights for high and low nutrition groups



Fat Score for high and low nutrition groups



Scanning Results

Foetuses	High Nutrition %	Birth Wt	Low Nutrition %	Birth Wt
0	18		19	
1	22	4.4	19	3.7
2	52	3.6	50	3.3
3	8	3.0	12	2.8
Ovulation Rate	2.5		2.4	

	High Nutrition	Low Nutrition
Foetuses/ewe joined (%)	150	156
Foetuses/ewe pregnant (%)	184	191
Lambs marked/ewe joined (%)	88	85
Lambs marked/ewe pregnant (%)	107	105

	High Nutrition	Low Nutrition
Lamb marking wt	9.1kgs	8.8kgs
Lamb birth day	178	176
Lamb birth wt	3.5	3.2
Lamb weaning wt	28	27
Ewe weaning wt	54	53
Lamb growth wt 22/7-7/10 (gm/day)	245	236

Discussion

The important finding from this study was that although the high nutrition group had a fat score of 3.6 at mating they did not produce only quad or quin born lambs.

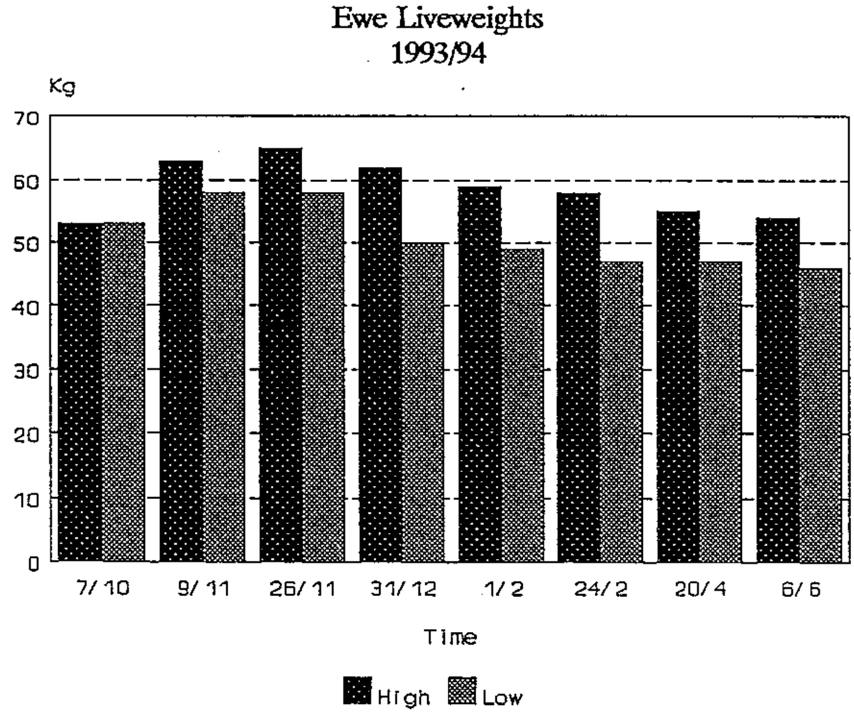
Another important finding was that weight loss over mating in young ewes causes a high incidence of dry ewes even if the ewes are still in good body condition. These are other finding support our recommendation that young ewes should be improving in liveweight over mating if a good conception rate is to be achieved. For summer mating this is not likely to produce any quad or quin births.

The third is that young ewes cannot cope with the same loss of condition during pregnancy as older ewes. In this trial, although the weight losses were not severe, the condition losses were. Young ewes are still growing during this period and so have an added nutritional requirement above that of the pregnancy. Failure to keep the young ewes in adequate condition leads to very low birth weights and poor lamb survival as in this experiment.

Our recommendation will therefore be that 1½ year old Booroola crossbreds should not be allowed to get below condition score 3 in pregnancy.

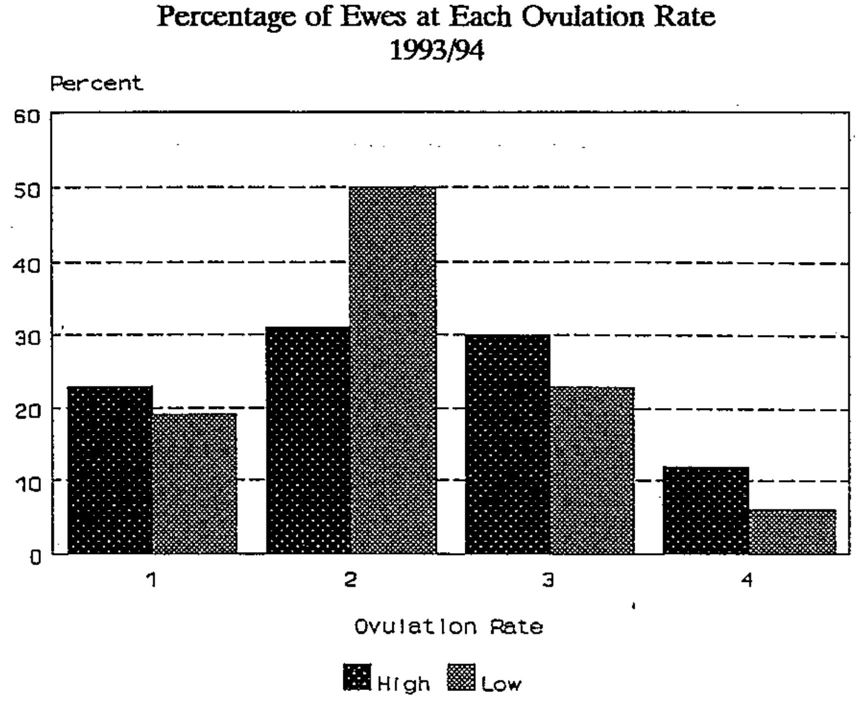
The effect of nutritional change on ovulation rate was investigated in a second experiment when the ewes were 2.5 years old.

Graph of Ewe Liveweights



In contrast to the previous years experiment the differences in nutrition were maintained during mating.

Graph of Ovulation Rates



The overall ovulation rate of the two groups were:

	High	Low
	2.43	2.15

Lambing Data

	High	Low
No ewes mated	116	118
No ewes lambing	112	115
Total lambs born	161	143
No lambs tagged	151	126
No lambs dead at birth	10	17
No lambs marked	106	104
Lambs marked/ewes lambing	95%	90%

Lamb Birth Weight		Kg	w	Survival	Kg	w	Survival
	1	4.3	(50)	80%	4.5	(47)	91%
	2	3.5	(59)	69%	3.7	(63)	71%
	3	3.1	(42)	41%	3.1	(14)	38%
Birth Day			180			183	
Marking Wt 9/8/94 (221)		12	(106)		12	(104)	
Wean Wt 21/11/94 (WW325)		36	(104)		36	(103)	

Discussion

Ewe liveweight did not fall so rapidly over mating (31/12 - 1/2) as in the previous year. This resulted in much higher conception rates. The continuation of the lower nutritional treatment during mating reduced the numbers of triplet born lambs. No quad or higher order litter sizes were recorded in either group. No nutritional supplementation was supplied in late pregnancy resulting in low birth weight and poor lamb survival in both groups.

The results of these two trials indicate that higher order births are not likely to be a problem in ewes under 2.5 years old when they are mated in summer. We know from our on property trials that young ewes mated in autumn can lamb at much higher rates but quads are still rare in young ewes.

Older Booroola crossbreds mated in Autumn at high liveweights do present a major problem. I have observed this on two private property trials. A recommendation to control the liveweight of Autumn mated older ewes to specified weights is included in our management booklet. At the Hamilton site at 4.5 years of age the ewes were mated in very high liveweights in Autumn. They were maintained in very good condition through to lambing. The very high litter sizes and birthweights were too much for the ewes to handle. The end result was low marking percentages and high ewe deaths. Unfortunately the trials conducted at Struan did not cover this type of situation but our management booklet (included later in this report) warns producers about this.

(v) Management of Booroola Crossbreds

The initial study below which has been published in Proceedings of the International Nutrition Society investigated the effects of different supplements on roughage consumption, ewe liveweight and lamb birth weight.

EFFECTS ON SUPPLEMENTS DURING LATE PREGNANCY ON ROUGHAGE CONSUMPTION AND LAMB BIRTH WEIGHT OF TWIN BEARING EWES

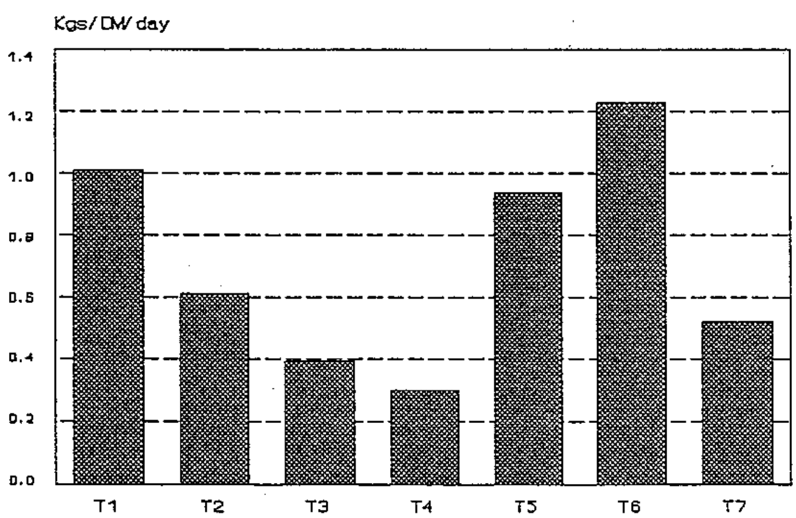
Earl C.R*, Dixon R.M†, Male R.H. and Rowe J.R. Department of Primary Industries, Struan, South Australia; †Department of Primary Industries,"Swans Lagoon", Millaroo, Queensland 4807 Australia.

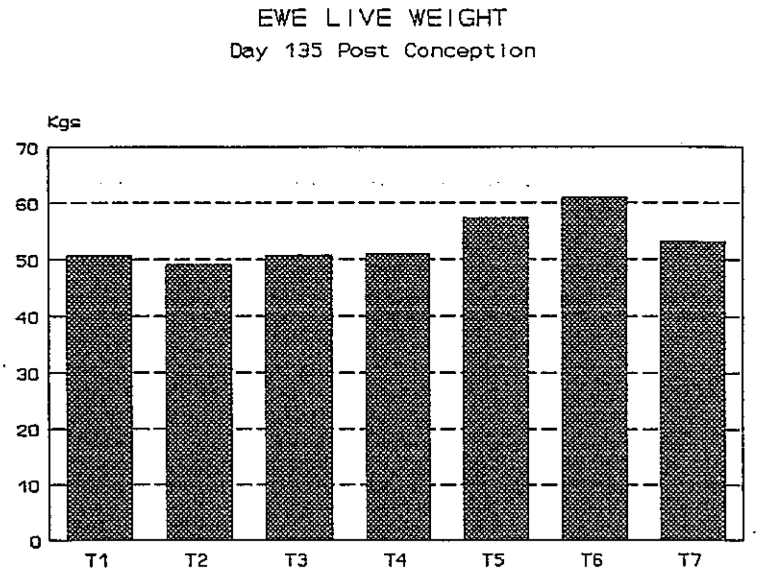
Seventy twin-bearing oestrus-synchronised BLxM ewes (LW 47.8kg) were housed indoors in individual pens and allocated by stratified randomisation based on LW to seven dietary treatments imposed from d 100 of pregnancy. Treatments 1-6 consisted of Nil, 200, 400 or 600 g/d of oat grain, 400 g/d of lupin grain or 300 g/d of cottonseed meal (CSM) supplement respectively with ad libitum chopped pasture hay roughage. Treatment 7 consisted of 300 g/d CSM with roughage intake restricted to that consumed by T3 ewes. Roughage contained 8.2 MJ ME/kg and 7.8% crude protein. Oats, lupins and CSM contained 9.8, 35.4 and 45.3% crude protein respectively. Results for intake (kg DM/d) and ewe LW (kg) after 4 weeks of the treatments and lamb birth weight (kg) (Table) indicated that roughage intake was severely depressed by oat grain, maintained by lupins and increased by CSM supplement. Lupins and CSM increased lamb birth weight, even when roughage intake was restricted, suggesting that lamb birth weight is influenced more by amino acid supply that ME supply in late pregnancy.

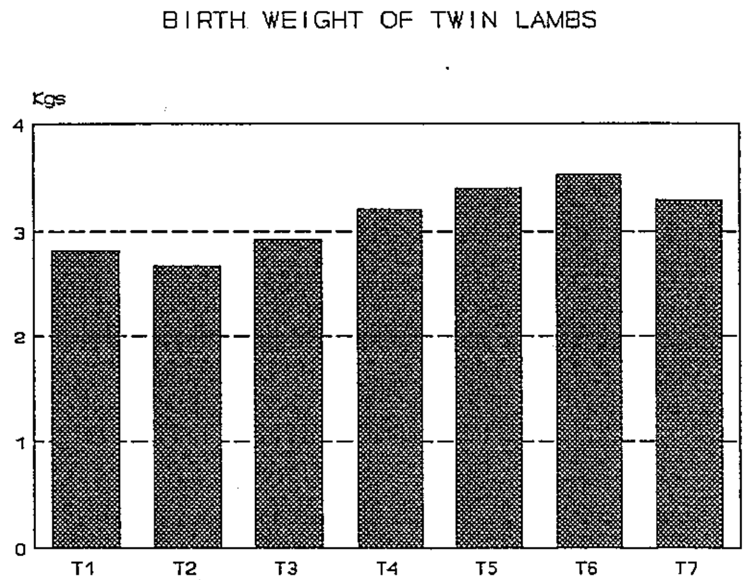
	T1	T2	T3	T4	T5	T6	T7
Rough intake kg/d	1.01^{a}	0.61^{c}	0.39^{b}	0.30^{b}	0.94^{a}	1.23^{d}	0.52^{e}
Ewe LW kg	50.7^{abc}	49.1^{a}	50.6^{abd}	51.0^{abe}	57.3^{c}	61.0^{b}	53.2^{cde}
Lamb birth wt kg	2.82^{ac}	2.67^{a}	2.93^{acf}	3.21c^{bde}	3.40^{b}	3.52^{bef}	3.30^{b}

Treatments followed by the same letter are not significantly different. $P<0.05$

ROUGHAGE INTAKE







These results form the basis of our recommendation that grain legumes are the preferred supplement to ewes in late pregnancy when ewes are on dry paddock feed.

Background

The previous year's results obtained from pen feeding trials suggested that high protein supplements gave much higher lamb birth weights than the most commonly used supplement, oats. This trial showed that oats depressed roughage intake, whereas cottonseed meal stimulated roughage intake and lupins had no effect on roughage intake.

In the second year similar supplementary feeding regimes were investigated under field conditions.

Aim

The aim of this years trial was to examine the effects of the same supplements ie oats, lupins and cottonseed meal on lamb birth weights, survival and growth under field conditions.

Methods

150 ewes were randomly allocated to 5 treatment groups on the basis of liveweight. The five treatment groups were;

T1	-	No supplementary food
T2	-	400 gms of oats/hd/day
T3	-	600 gms of oats/hd/day
T4	-	400 gms of lupins/hd/day
T5	-	300 gms of cottonseed meal/hd/day

Feeding to commence 4 weeks prior to the onset of lambing and continued for 6 weeks.

Treatments	Born	Weaned %	n	Bth singles	Wt n	Bth Wt Twins	Weaning Weights Singles	Twins
T1	33	16 (43)	13	5.1	20	3.2	33	29
T2	44	24 (54)	12	4.7	32	3.6	32	29
T3	48	24 (50)	12	5.1	36	3.5	34	34
T4	40	23 (57)	14	4.9	26	3.7	34	30
T5	0	21 (52)	16	4.6	24	3.5	33	29

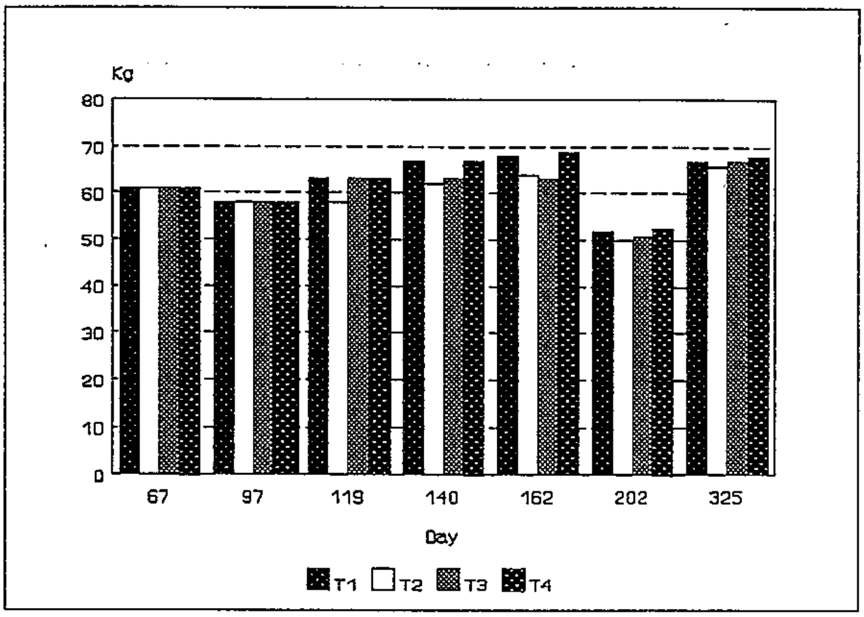
There was no difference in birth weight of singles between treatments. All supplementary feeding treatments improved the birth weight of twins. Although there were no significant differences between the supplementary feeding treatments the trend supports our recommendation that lupins are probably the best supplement for prolific ewes in this region because of their improvement of multiple lamb birth weights and their ready availability.

Lamb Survival Experiment 1994

Crossbred ewes were randomly divided on the basis of liveweight to 4 equal treatment groups. The period from 9 weeks before lambing was divided into 3 treatment periods of 3 weeks to investigate the effects of liveweight changes during different periods prior to lambing on lamb birthweight and survival. The control group remained on good nutrition throughout the treatment period. The remaining three groups each received a period of nutritional restriction for one of the three, 3 week periods.

Ewe Liveweights

Prelambing



T1	=	Control
T2	=	Restriction first three weeks
T3	=	Restriction second three weeks
T4	=	Restriction last three weeks

Lambing Data

Lambing Data											
	Birth Wts			Birth Day	Birth Wts				Mark Wt	Wean Wt	No
	I	II	All		Males		Females				
					1	2	1	2	202	325	
Control	5.4 (14)	4.8 (24)	5.0 (38)	165	5.6	4.8	5.4	4.7	12	44	36
T1	6.0 (15)	4.7 (24)	5.2 (39)	166	6.4	4.8	5.5	4.7	14	46	33
T2	5.7 (19)	4.1 (12)	5.1 (31)	166	5.9	4.4	5.0	3.9	15	46	30
T3	5.5 (11)	4.4 (22)	4.8 (33)	165	6.0	4.6	4.7	4.2	13	44	32

There were no significant differences between treatments. All groups showed high birthweights and excellent lamb survival rates. All treatments were over 63kg and fat score 3.3 prior to lambing. This supports our recommendation that ewes must be in fat score 3 or better at lambing and suggests that 60kg or better should be the liveweight target.

It is of interest that T4 the restriction during the last 3 weeks did not produce a poorer result. These ewes did not lose weight and suggests that our restriction during this period was not very severe although there seemed to be little available feed.

Further studies directed at determining the role of the placenta in determining birth weight and survival were also conducted as a part of DAS 27 at Struan. These studies were part of a PhD project conducted by Tania Jarvis. Some of these results are contained in the following paper.

MATING WEIGHT INFLUENCES THE EFFECT OF MID-PREGNANCY NUTRITION ON PLACENTAL GROWTH IN THE SHEEP.

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The impact of maternal live weight and associated body reserves at mating on the response of the placenta and fetus to variations in nutrition during mid-pregnancy was studied. Two levels of nutrition, high (H) and low (L) were imposed during days 30-90 post conception (p.c.) on ewes of heavy (He) and light (Li) mating weight, generating 4 treatment groups; heavy ewes, high plane nutrition (HeH), heavy ewes, low plane nutrition (HeL), light ewes, high plane nutrition (LiH) and light ewes, low plane nutrition (LiL).

Mating weight determined the response of the placenta of single bearing ewes to subsequent mid-pregnancy nutrition such that a change in nutrition eg.HeL, LiH, enhanced placental weight relative to that of continuously well fed ewes (HeH). Fetal weight and crown-rump length (CRL) were moderately affected by mating weight, He ewes having larger foetuses than light ewes. Only CRL was influenced by mid-pregnancy nutrition, decreasing with nutritional restriction. The treatments associated with increased placental size were also associated with an increase in weight of key fetal organs compared with those from well fed ewes (HeH).

We conclude that the mating weight of single bearing ewes determines placental growth in response to variations in mid-pregnancy nutrition. A larger placenta is associated with heavier key fetal organs suggesting increased function may accompany enhanced placental weight. Fetal weight and CRL continue to largely reflect mating weight. The stimulus to the mechanisms involved in compensatory placental growth remain to be determined.

Nutrition: Pregnancy: Placenta: Sheep: Fetus

The importance of the placenta in fetal development is undisputed as it is the primary site of transfer of nutrients derived from both exogenous (nutrition) and endogenous (body reserves) maternal sources. The close statistical association between placental weight and lamb birth weight which emerges in late gestation (Alexander 1964; Davis et al. 1981) is consistent with a strong placental influence on fetal growth rates and lamb birth weight. The development of the ovine placenta is influenced by numerous factors including maternal age, breed and parity, early embryo mortality, number of foetuses, high environmental temperatures and maternal nutrition. Of these, the most influential are nutrition and heat stress (Bell 1984). Hence the impact of variable nutrition on fetal growth will depend partly on any effect on placental growth.

The influence of nutrition on placental growth is incompletely understood. A major difficulty has been that studies of the consequences of varying nutrition during the period of rapid placental growth ie. days 30-90 of gestation, have produced conflicting conclusions. Restriction of maternal nutritional intake during mid - pregnancy has been associated with both enhancement (Faichney & White 1987; McCrabb et al. 1992a) and suppression of placental growth (Everitt, 1964; Morris, 1973; Mellor, 1983 & McCrabb et al. 1986, 1992a,b). Concomitantly both reduced (Everitt, 1964; Morris, 1073; Curll et al. 1975; Rattray & Trigg, 1979; Russel et al. 1981, Mellor, 1983, Nordby et al. 1985) and increased lamb birth weight have been described (Everitt, 1965; Russel et al. 1981; Holst et al. 1986). The origin of the variable impact of restrictions on placental and fetal development in these studies is unclear but could result from differences in the severity, duration and timing of such restrictions between studies (Everitt 1965; Mellor 1983). Alternatively, unrecognised variations in maternal reserves at mating may be responsible (Russel et al. 1981, Mc Crabb et al. 1992).

The objectives of this experiment were therefore to determine the effects of nutritional restriction during days 30-90 of gestation on placental and fetal development at day 90 p.c. in ewes of heavy (He) and light (Li) mating weight.

MATERIALS AND METHODS

Animals and Location

This experiment was conducted at Struan Research Centre, 16km south of Naracoorte, South Australia. A flock of 460 parous Border Leicester X Merino ewes were divided on the basis of live weight into 2 groups of 230 ewes. Prior to mating, the nutritional intake of each group was controlled by stocking rate to produce a heavy mating weight (>60kg for ewes of this genotype, He) and a light mating weight (at least 10kg below He, (Li)) on the 1 January 1991.

In October 1990 all ewes were treated with melatonin (Regulin, Genelink, Australia, Ltd.) and immunised against androstenedione (Fecundin, Glaxo, Australia, Ltd.) to increase the incidence of multiple births.

The oestrous cycles of the ewes were synchronised using progestagen sponges (Repromap, Upjohn) and the two mating weight groups were then combined and 17 Poll Dorset rams harnessed with mating crayons (Radford et al 1960) introduced. Ewes were observed daily for crayon marks for a period of 5 days.

Feeding Regime

Live weight of the ewes was maintained at either He or Li levels throughout the mating period and up until day 30 post conception (p.c.) (period I) when the nutritional treatments commenced. At this time all ewes not raddled were removed from the experiment.
Period II commenced on day 30 p.c. when each mating weight group was divided by random allocation following stratification on the basis of live weight into a high (H) or low (L) plane of nutritional treatment. The nutritional intake of the ewes was controlled by pasture management and supplementation of clover-grass hay three times per week to the H group. Hence 4 treatment groups were generated HeH, HeL, LiH, LiL.

All ewes were scanned on day 60 p.c. using real time ultrasound (Fowler and Wilkins 1982, brand and model?) and non-pregnant ewes culled from the experiment.

Each of the 4 treatment groups were replicated 3 times.
At the end of period II, a sub-sample (n=48) of ewes were slaughtered.

Measurements

Ewe live weight and their condition score (5 point scale, Russell et al 1969) were recorded every 14 days throughout the experiment. Samples of blood from the jugular vein were collected monthly, centrifuged and plasma frozen at -20°C for later analyses, to be reported separately.

Day 90 p.c. post-mortem.

Six singleton and 6 twin bearing ewes from each treatment were selected according to live weight and condition score on day 89 p.c. for slaughter at the end of the nutritional restriction period (Day 90 p.c.). Autopsy data included the total weight of the gravid uterus, wet weight of the fetus after excess fluid wrung off by hand and lightly wiped with paper towel(twins presented as individual foetuses), sex of fetus, curved crown-rump length(CRL), thoracic girth, weight of fetal organs; kidneys, adrenal glands, liver, gut, spleen, lungs, heart, chest and neck thymus, thyroid glands and brain weight. All individual cotyledons were removed, trimmed of membranes to the surface of the cotyledon and weighed. Their total weight was defined as placental weight, placental weight of individual twins was analysed and presented separately.

Ewe carcass weight (skinned and free of internal organs), weight of liver, heart and left kidney, peri-renal and dissectible rump-fat deposits and semi-tendonosus muscle were recorded.

Statistical Analyses

The data were analysed using analyses of variance procedures and the general linear models program SAS (Statistical Analysis System, 1988). Fetal sex was not a significant factor and as such, was eliminated from the analysis. Results are presented as means and standard deviation.

RESULTS

Live Weight

Pre-mating nutritional treatments produced ewe live weights of 63±3kg in the heavy (He) and 51±2kg in the light (Li) groups at mating respectively (Fig. 1, Table 1). Ewe live weight at day 0 did not influence the number of ewes not mated, 13% and 19% in heavy and light weight groups respectively, nor the numbers of non-pregnant ewes removed from the experiment after scanning (9%, 4%, 10% and 6% in the HeH, HeL,LiH and LiL groups respectively). Unrestricted nutrition treatment (days 30-90 p.c.) increased ewe live weight (1kg HeH, 8kg LiH) and restricted nutrition treatment decreased ewe live weight (11kg HeL, 8kg LiL). Ewe condition scores were higher in the He ewes (4.3±0.3) compared to the Li ewes (2.9±0.3) at mating (Table 1). Condition score paralleled changes in live weight throughout each of the treatments during the experiment and were different at days 30 (HeH 4.8±0.1, HeL 4.7±0.2, LiH 3.0±0.1, LiL 3.0±0.3) and 90 p.c.(HeH 4.4±0.4, HeL 3.6±0.4, LiH 3.4±0.2, LiL 2.0±0.6), reflecting the nutritional treatments imposed on the ewes (Table 1).

Maternal Carcass

Restricted nutrition (days 30-90 p.c.) reduced ewe carcass weight (p=0.01) at day 90 p.c., the magnitude of the change being influenced by ewe live weight and by associated body reserves (as reflected by condition score) at mating (p=0.003). Thus heavy mating weight ewes subjected to nutritional restriction were 5kg or 18% lighter and light mating weight ewes were 3kg or 15% lighter than their respective well fed counterparts at day 90 p.c.(Table 1). Heavy mating weight ewes had heavier peri-renal fat (18%,p=0.002) and M.semitendinosus (22%,p=0.008) than light mating weight ewes irrespective of mid-pregnancy nutrition (Table 2). Mid-pregnancy nutritional restriction reduced peri-renal fat (21%), (p=0.0004), dissectible rump fat (27%), (p=0.002) and weights of maternal heart (11%), (p=0.01) liver (13%), (p=0.06) and left kidney (16%), (p=0.0003) in both heavy and light mating weight ewes (Table 2). Organ sizes did not differ significantly between single and twin bearing ewes.

Placental Growth

Placentas of single lambs were heavier (20%) than those of individual twin lambs (p=0.0006) (Fig. 2). The influence of pregnancy nutrition on placental weight was related to mating weight (p=0.06) in single bearing ewes, but not in twin bearing ewes. Nutritional restriction during pregnancy of ewes carrying singles enhanced placental weight by 21% in heavy mating weight ewes, when compared to their well fed counterparts (HeH). Conversely, unrestricted pregnancy feeding increased placental weight in the light mating weight ewes by 23% compared to the heavy (HeH). Unexpectedly, placental weight of LiL ewes was not significantly different to those of well fed ewes (HeH). In contrast to ewes carrying singles, mating weight alone affected twin placental weight (p=0.03), light mating weight ewes having heavier placentae (13%) irrespective of variations in subsequent pregnancy nutrition.

Nutrition during mid-pregnancy influenced the number of cotyledons in each placenta, those from ewes of the LiH treatment having significantly more cotyledons (p=0.03), than the HeH (25%), LiL (33%) treatments and HeL (15%) (did not reach statistical significance). Singleton placentae were composed of a greater number of cotyledons than the placentas of individual twins (54%, p=0.0001). In contrast to singleton placentae, the number of cotyledons in twin placentae were not significantly influenced by nutrition.

Fetal Growth

Single and twin foetuses had similar weights at day 90 p.c. and while pregnancy nutrition did not affect fetal weight, foetuses from the He mating weight ewes tended to be heavier (p=0.08) than those from Li ewes (Fig. 3). Similarly, fetal CRL was significantly but only slightly higher in those foetuses carried by He compared to Li mating weight ewes (p=0.05)(Table 3), while restricted mid- pregnancy nutrition also reduced CRL slightly (p=0.03). Fetal head dimensions were significantly but moderately affected by the treatments, light mating weight ewes with restricted mid-pregnancy nutrition treatments producing foetuses of the smallest head dimensions. Thoracic girth was not significantly affected by treatment.

F:P ratios were higher (23%) in twin bearing ewes than singletons (p=0.002). Mating weight (p=0.08) but not mid-pregnancy nutrition moderately affected F:P ratios, He ewes at mating having higher (21%) F:P ratios.

Fetal Organ Weight

Although mating weight alone tended to be the sole influence on fetal weight, only weight of the thyroid (p=0.02, 11%) and chest thymus (p=0.04, 16%) were reduced by a Li compared to a He mating weight in foetuses at 90 days p.c.. Restricted mid pregnancy nutrition also reduced thyroid weight (p=0.05, 9%) irrespective of mating weight. Weight of several major fetal organs/tissues were influenced by interactions between mating weight, mid-pregnancy nutrition and fetal number. Mating weight and mid pregnancy nutrition interacted to increase the weight of fetal heart (p=0.03), chest thymus (p=0.04), liver (p=0.003) and brain (p=0.05), the foetuses from the two treatment groups which exhibited enhanced weight in singleton placentae (HeL, LiH) having heavier organs than foetuses from the HeH and LiL treatments. In addition, mid pregnancy nutrition and fetal number interacted to affect thyroid weight ($p=0.004$), which was also influenced by the interaction between maternal live weight at mating and fetal number ($p=0.002$). The three way interaction also influenced the weight of the spleen ($p=0.004$), lung ($p=0.04$), gut ($p=0.005$), heart ($p=0.006$), liver ($p=0.0008$) and brain ($p=0.05$).

Table 5 shows the effects of treatments on growth parameters and individual organs relative to fetal body weight; that is, on the symmetry of fetal growth. Mating weight and mid-pregnancy nutrition interacted to moderately affect relative CRL ($p=0.04$), restricted nutrition in He mating weight ewes producing foetuses of reduced CRL (9%) or short-for-weight but increased CRL or long-for-weight in foetuses from Li ewes at mating (11%) compared to foetuses from the well fed ewes in each mating weight group. Relative thoracic girth was significantly but only slightly affected by mating weight ($p=0.007$), Li ewes at mating having foetuses with larger thoracic girths relative to body weight (7%) than foetuses from He ewes. Several key fetal organs were influenced by the treatments relative to fetal body weight. Liver growth relative to whole body weight was stimulated by restricted mid-pregnancy nutrition in heavy ewes at mating ($p=0.004$, 13%), in contrast to the light mating ewes in which restricted nutrition adversely affected relative liver growth (10% reduction). Pregnancy nutrition interacted with fetal number to slightly influence lung ($p=0.02$) and liver weight ($p=0.002$), singletons having larger lungs and livers relative to body weight than twins in unrestricted nutrition treatment; but twins having larger lungs than singletons, in restricted nutrition treatments. The three way interaction influenced total kidney weight relative to body weight ($p=0.01$), single and twin foetuses having similar kidney weights in all treatments, except HeL where twins had larger kidneys relative to body weight than singletons. Relative gut weight ($p=0.04$) was also influenced by this interaction and was similar in both singles and twins in all treatments, except LiL where twins had heavier gut weights relative to body weight (11%) than singletons. The relative growth of the spleen was the only organ influenced by mating weight ($p=0.04$,) heavy ewes at mating producing foetuses with smaller spleens relative to body weight than light weight ewes (12%).

…ble 1: *Ewe live weights(LWT), condition scores(CS) and carcass weight at day 90p.c. (mean±std.deviation).*

…T	FETAL NO.	LWT (DAY0)	CS (DAY0)	LWT (DAY30)	CS (DAY30)	LWT (DAY90)	CS (DAY90)	CARCASS WEIGHT (DAY90)
…H	1 (n=6)	65.8±1.3	4.7±0.4	63.2±1.9	4.9±0.2	65.2±3.5	4.6±0.5	28.4±2.4
	2 (n=6)	62.8±5.4	4.2±0.5	60.7±4.7	4.7±0.4	63.7±6.7	4.1±0.2	26.9±4.5
…L	1 (n=6)	64.7±6.0	4.3±0.4	62.0±5.7	4.8±0.3	53.0±6.5	3.8±0.7	24.3±3.9
	2 (n=6)	59.3±3.9	4.1±0.2	57.3±4.5	4.5±0.0	48.7±3.6	3.3±0.3	20.8±2.3
…H	1 (n=6)	49.7±2.6	3.2±0.4	50.0±2.5	3.0±0.5	57.5±2.7	3.4±0.4	21.2±1.3
	2 (n=6)	51.3±5.3	3.1±0.2	53.5±5.3	3.0±0.3	58.0±6.6	3.4±0.4	21.7±3.8
…L	1 (n=6)	52.5±5.3	2.5±1.2	51.8±5.1	3.2±0.5	44.7±5.6	2.4±1.0	19.4±4.2
	2 (n=6)	49.0±5.2	3.1±0.2	49.5±4.6	2.8±0.5	42.3±5.1	1.5±0.0	17.1±2.1

…able 2: *Ewe organ, fat and muscle depot values, day 90 p.c. (mean ±std. deviation)*

…T	Fetal NO.	LIVER	HEART	KIDNEY	RUMP FAT	RENAL FAT	SEMI -TENDONOSUS
…H	1 (n=6)	680.7±23	278.3±36	61.2±7	108.2±52	988.8±464	146.3±11
	2 (n=6)	726.7±165	254.8±14	66.5±9	83.7±76	726.7±166	136.0±25
…L	1 (n=6)	684.2±89	253.2±37	57.0±2	68.5±19 6	84.2±89	108.5±19
	2 (n=6)	661.3±61	250.3±42	54.8±6	95.3±12 6	61.3±61	95.3±11
LH	1 (n=6)	666.8±63	288.3±67	60.3±7	120.3±22	666.8±63	120.3±22
	2 (n=6)	736.0±151	263.2±44	70.0±16	112.0±11	736.0±151	112.0±11
…	1 (n=6)	535.3±76	223.0±31	47.3±4	73.5±2	535.3±76	73.5±2
	2 (n=6)	569.3±79	243.5±38	57.2±14	73.2±23 5	69.3±79	73.2±23

le 2A: *Placental weight, cotyledon number and fetal:placental(F:P)ratio* (*mean*±*std.deviation*)

mt	FETAL NO. NO.	PLACENTAL WEIGHT	COTYLEDON NUMBER	F:P
H	1 (n=6)	462±74	70.0±7.0	1.73±0.13
	2 (n=12)	379±65	49.9±4.2	2.40±0.12
leL	1 (n=6)	561±126	79.7±6.4	1.68±0.16
	2 (n=12)	392±61	47.6±4.9	2.14±0.08
iH	1 (n=6)	569±144	93.5±6.4	1.29±0.22
	2 (n=12)	448±105	51.8±4.5	1.90±0.12
	1 (n=6)	454±110	63.0±6.4	1.49±0.18
	2 (n=12)	423±76	49.3±4.5	1.60±0.13

le 3: *Parameters of fetal growth at day 90p.c.* (mean±std.deviation).

MT	FETAL NO.	C-R LENGTH	THORACIC GIRTH	HEAD WIDTH	HEAD LENGTH
H	1 (n=6)	338.3±20.7	194.0±1.4	45.7±1.5	87.5±2.9
	2 (n=12)	342.3±20.8	199.7±6.1	47.3±2.5	90.7±4.1
HeL	1 (n=6)	333.5±9.3	204.7±4.7	46.8±3.9	89.0±4.4
	2 (n-12)	313.2±31.6	196.4±7.6	47.0±1.7	87.5±2.5
I	1 (n=6)	326.5±13.0	199.3±8.1	47.7±1.8	88.0±4.1
	2 (n=12)	326.3±13.4	196.6±8.3	45.6±2.9	88.2±2.52
	1 (n=6)	319.8±15.5	200.0±0.0	44.83±2.6	82.2±4.6
	2 (n=10)	319.2±18.7	197.4±10.9	46.2±1.9	85.5±3.8

ıle 4: *Fetal organ weights at day 90p.c. (mean ±std.deviation).*

MT	HeH		HeL		LiH		LiL	
~tal NO.	1	2	1	2	1	2	1	2
.GAN								
IVER	42.3±7.9	48.8±6.8	56.5±3.1	50.7±4.7	55.3±6.6	49.2±7.4	37.9±7.0	44.83±7.8
AIN	20.5±1.4	22.0±2.3	23.0±2.1	22.1±1.8	21.7±1.8	21.8±1.7	18.9±2.8	20.9±2.0
HYROID	0.46±0.16	0.36±0.06	0.37±0.05	0.35±0.07	0.35±0.05	0.35±0.05	0.25±0.03	0.034±0.07
.EEN	1.3±0.3	1.6±0.3	1.6±0.3	1.3±0.2	1.5±0.3	1.4±0.3	1.0±0.3	1.2±0.3
UNGS	36.3±4.3	37.4±5.3	39.7±3.2	36.8±3.0	37.9±1.3	36.7±5.7	29.5±7.3	35.0±5.7
.T	34.6±8.6	39.2±7.6	42.5±5.3	36.0±3.8	37.9±4.3	36.8±4.7	27.9±7.9	26.5±6.2
. THYMUS	0.99±0.3	0.96±0.2	1.11±0.4	1.02±0.1	1.12±0.2	0.85±0.3	0.74±0.3	0.76±0.2
. THYMUS	2.0±0.7	2.0±0.6	1.6±1.1	1.5±0.6	1.4±1.3	1.2±0.9	1.3±0.4	1.1±0.5
ART	6.8±1.7	8.2±1.0	8.5±1.2	7.6±0.7	7.7±1.3	7.9±1.1	5.6±1.4	7.3±1.1
IDNEYS	8.1±0.9	8.2±0.9	8.0±0.9	8.0±1.2	7.7±1.0	8.0±1.6	6.7±0.9	7.7±1.5
RENALS	0.16±0.08	0.18±0.04	0.17±0.03	0.15±0.04	0.16±0.04	0.15±0.03	0.12±0.03	0.15±0.05

ıle 5: *Fetal organ weights relative to fetal weight at day 90p.c. 9mean ±std.deviation).*

MT	HeH		HeL		LiH		LiL	
etal NO.	1	2	1	2	1	2	1	2
GAN								
IVER	5.3±0.4	5.2±0.2	6.0±0.6	6.0±0.5	6.9±2.0	5.8±0.6	5.6±0.5	5.6±0.7
AIN	2.6±0.24	2.4±0.21	2.4±0.20	2.6.0±0.26	2.7±0.66	2.6±0.14	2.8±0.27	2.6±0.20
HYROID	0.06±0.02	0.04±0.01	0.04±0.005	0.04±0.008	0.04±0.01	0.04±0.007	0.04±0.007	0.04±0.01
.EEN	0.16±0.03	0.18±0.03	0.17±0.03	0.15±0.02	0.18±0.03	0.16±0.3	0.15±0.02	0.15±0.2
UNGS	4.6±0.2	4.0±0.3	4.2±0.3	4.4±0.4	4.7±0.9	4.3±0.4	4.3±0.4	4.3±0.3
T	4.3±0.6	4.2±0.5	4.5±0.3	4.3±0.4	4.7±0.6	4.3±0.4	4.1±0.5	4.6±0.7
H. THYMUS	0.12±0.03	0.10±0.02	0.12±0.04	0.12±0.01	0.14±0.04	0.10±0.03	0.11±0.03	0.09±0.02
THYMUS	0.24±0.05	0.22±0.05	0.16±0.1	0.18±0.07	0.19±0.2	0.14±0.1	0.19±0.4	0.14±0.07
ART	0.84±0.1	0.88±0.1	0.89±0.1	0.90±0.08	1.0±0.3	0.93±0.1	0.82±0.08	0.93±0.1
DNEYS	1.0±0.07	0.90±0.1	0.84±0.09	0.95±0.1	0.95±0.2	0.94±0.1	0.96±0.07	0.95±0.1
RENALS	0.02±0.008	0.02±0.005	0.02±0.002	0.02±0.005	0.02±0.009	0.02±0.004	0.02±0.004	0.02±0.005
ARAMETER								
. LENGTH	42.9±4.9	39.0±9.1	35.3±1.7	37.2±3.9	40.8±9.3	38.7±3.11	48.8±10.8	40.9±4.5
H. GIRTH	21.2±0.04	20.9±1.2	21.7±1.3	23.3±1.0	24.9±5.5	23.3±1.7	24.1±1.9	
. WIDTH	5.8±0.6	5.3±0.7	5.0±0.3	5.6±0.3	5.9±1.0	5.4±0.4	6.8±1.4	5.9±0.8
ID. LENGTH	11.1±1.1	9.9±1.1	9.4±0.5	10.4±0.5	11.0±2.5	10.5±0.9	12.5±2.4	11.0±1.2

DISCUSSION

Restricted nutritional intake during the second and third months of gestation reduced ewe live weight by 18% (HeL) and 15% (LiL), in contrast to unrestricted nutrition which was associated with gains of 1% and 15% in the HeH and LiH groups respectively. Fat and protein deposits were depleted by restricted nutrition indicating that the ewes were mobilising their energy reserves, presumably because exogenous feed supplies were insufficient to maintain maternal and growing conceptus metabolic requirements. Live weight losses in excess of 5% during this period have been shown previously to reduce placental growth (Davis et al 1981; Robinson 1983), however this was not observed.

Instead, the effect of mid-pregnancy nutrition on day 90 p.c. singleton placental weight was dependent upon ewe live weight at mating, ewes from the treatments HeL and LiH exhibiting enhanced placental weight compared to the well fed ewes (HeH). This suggests that previous conflicting results in other experiments may originate from unrecognised differences in maternal live weights and/or condition scores at mating.

A reduction in placental growth due to underfeeding prior to day 100 of gestation was found by Everitt (1964); Morris (1973); Mellor (1983) and McCrabb et al (1986, 1992a,b). In contrast, our results show that mid-pregnancy nutritional restriction did not adversely affect placental size in LiL ewes compared to the HeH treatment.

Although increases in placental weight due to undernutrition in mid-pregnancy have been reported elsewhere by McCrabb et al (1992a) this was over two years where treatment groups were not studied simultaneously. Stimulation of placental growth through undernutrition was hypothesised by McCrabb et al. (1992a) to be due to the additional endogenous production of substrates mobilised from the large body reserves present in the heavy ewe at mating. However, the condition scores of the Mc Crabb et al. (1992a) study suggest that body reserves were in fact similar between the two live weight groups (2.7 vs. 2.5). This contrasts with the current study where condition scores at mating were vastly different between the two mating weight groups (4.3 vs. 2.5). In addition, substrate levels would appear unlikely to have been higher in a HeL treatment than in the well fed ewe. The mobilisation of body reserves in the HeL treatment was presumably sufficient to sustain enhanced placental growth, while in the LiL treatment, at least "normal' placental growth was maintained. If placental growth is simply related to substrate level as suggested by McCrabb et al. (1992a), then placental weight should have been equally stimulated in the well fed heavy ewe. These ewes would have had higher plasma substrate levels than the He underfed, ewes as indicated by the loss in live weight and associated body reserves by HeL ewes compared to a gain in live weight in the HeH treatment ewes over the treatment period. The nature of the stimulus for placental growth hence remains unclear. We suggest that as enhanced placental weight was observed in the HeL treatment whilst the ewes were rapidly losing weight, some mechanism must exist to preferentially direct substrates to the conceptus at the expense of other tissues (eg fat and muscle).

Teleologically, it is attractive to have increased placental size in response to varying maternal nutrition, as this would protect the fetus against continuing variation in maternal nutrition during the remainder of pregnancy. This study shows that despite what are presumably lower concentrations of nutrients in maternal blood in the HeL treatment, compared with the HeH, placental growth is actually enhanced. This suggests that a specific signal or stimulus to compensatory growth is present. The similar response in the LiH treatment suggests that whatever the nature of this stimulus, it must be common to both treatments or that several factors are capable of increasing placental growth. The LiH treatment showed a tendency to recruit additional implantation sites compared to other treatments, suggesting the latter is more likely. In contrast to the patterns of growth observed with enhanced placental weight associated with pre-mating carunclectomy (Alexander 1964; Robinson et al. 1979) and nutritional restriction (McCrabb et al. 1992a) where the size of individual cotyledons was larger, our results showed no significant differences in average cotyledon weight. There were however differences in cotyledon numbers associated with enhanced placental weights suggesting that enhancement was achieved through the recruitment of additional implantation sites.

The ability of the ovine placenta for compensatory growth in the first half of pregnancy is well recognised in numerous situations such as; multiple fetal numbers, pre-mating carunclectomy (Alexander 1964; Robinson et al. 1979) and unilateral fetectomy in twin bearing ewes (Vatnick et al. 1991) ablation ??. The present study shows that variable maternal nutrition is also capable of inducing compensatory placental growth.

The most significant influence on twin placental weight was maternal live weight at mating, hence mid-pregnancy nutrition had no affect on placental growth. The twin placenta however, has one fewer mechanism for enhanced placental growth than the singleton placenta, due to the presence of an additional fetus which restricts the number of cotyledons available for recruitment quite early in pregnancy.

Fetal weight and CRL were slightly affected by mating weight but only mid-pregnancy nutrition continued to influence CRL. In contrast to placental weight, fetal weight of singletons and twins was not significantly influenced by the nutritional treatments. This result was not unexpected as the fetus has attained only 15% of its birth weight by day 90 of gestation (Robinson & McDonald 1979). Although gross measurements of overall fetal growth were not greatly affected by the treatments, that of major fetal organs were. Different organs exhibit differential susceptibility to the treatments possibly dependant on their phase of growth during the nutritional restriction. External fetal measurements were not in all cases retarded in accordance with overall growth (fetal weight) and suggest asymmetric growth. Treatment differences in the relative growth of organs such as the spleen, liver, lungs and thyroid indicate that normal organ:tissue relationships were not maintained. It is interesting to note that the treatments which were associated with enhanced singleton placental weight (HeL, LiH) relative to well fed ewes (HeH) produced foetuses (both singles and twins) with enhanced weight of key fetal organs such as the heart, liver, brain and chest thymus. At this stage of pregnancy (day 90 p.c.) the effects on fetal organ growth of substrate limitations could well be exacerbated by altered thyroid hormone production. Hence the effects of the treatments on the reduction of the weight of key organs and the spleen (reduced emergency red blood cell supplies), chest thymus (impaired immune system response)(Alexander 1974) and thyroid would have important implications for subsequent fetal growth and ultimately, survival of the newborn lamb. In addition, by this stage future research should be directed toward identifying the nature of both the stimulus/i involved in enhancing placental weight and of the placental growth response itself. Also of major importance is the degree to which the differential effects of variable nutrition both prior to and during gestation on placental weight, alter the functional capability of the placenta and hence subsequent fetal growth.

The authors are grateful to J. Rowe, R. Male and C. Windebank for their assistance during this study. This research was generously supported by the Meat Research Corporation. T.M. De Barro gratefully acknowledges receipt of a Meat Research Corporation Junior Research Fellowship.

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The results of all our experiences in the management of Booroola Crossbreds have been summarised in the following pamphlet "Management of Booroola Crossbreds in South Eastern Australia". This booklet has been direct mailed to at least 70% of the Prime Lamb Producers in South Australia and provided to all ram buyers at our Struan sales.

Management of Booroola Crossbreds
in South Eastern Australia

Colin Earl
Struan Research Centre

The biggest single factor affecting prime lamb profitability is the number of lambs sold per hectare. To optimise this factor you need well managed prolific ewes.

Booroola crossbreds have very high lambing percentages and as such must be managed accordingly. As an example of their prolificacy their average lambing percentages as ewe lambs and adults are presented below.

	0	1	2	3	4	Total
Ewe lambs	14	29	44	12	1	157
1½ yr old	4	25	46	25	0	192
2½ yr old and mature	3	20	48	27	2	205

These figures will vary with nutritional treatment and the time of year at which you lamb with the figures increasing with body weight and later times of lambing.

Management of Ewe Lambs and 1.5yr Olds

These two groups of ewes have been lumped together because they are particularly sensitive to nutritional variations. In particular they are very sensitive to any weight loss over mating. It is very important that you try and have them gaining weight if even only very slowly.

Ewe lambs are the most sensitive to age and liveweight. They should be at least 10 months of age at the start of joining, a minimum of 40kg liveweight and gaining weight over joining to get a good result.

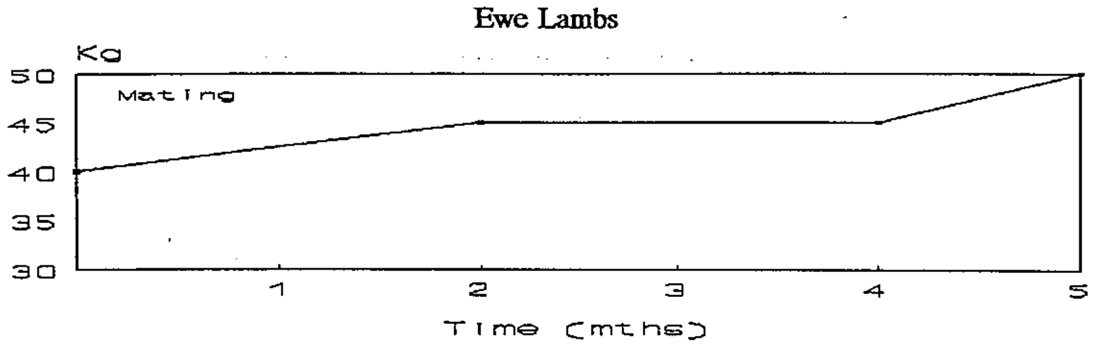
One and a half year olds should be a minimum of 50 kg liveweight at joining and gain weight over the joining period.

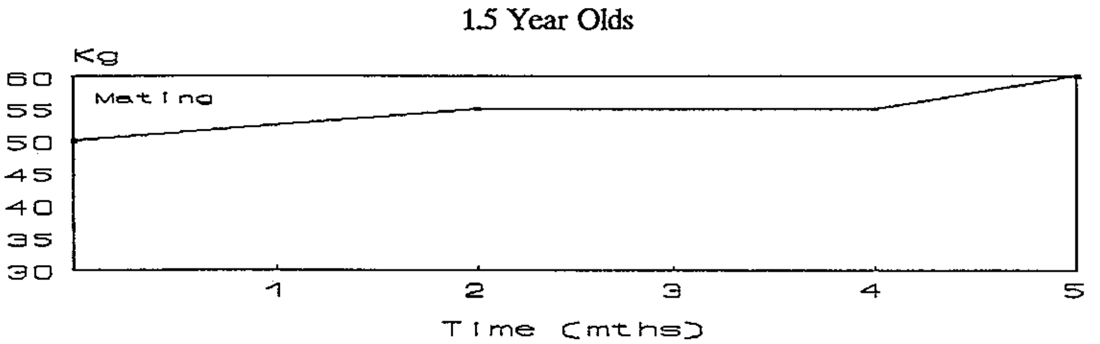
These two groups of ewes will generally have lower liveweight reserves than older ewes therefore they need better treatment through pregnancy. They have lower liveweights therefore cannot afford to lose as much. As a general rule they should not be allowed to drop below condition score 3 at any time during pregnancy. They should not be run with older ewes but kept separate so their particular needs can be catered for.

During late pregnancy (ie last six weeks) they should at least be gaining in weight even if only slowly. For this reason it may be better to lamb them a little later when there is a greater chance of green feed being available. However be careful that this objective is not obtained at the expense of them losing weight over mating. There is a trade off here with these young sheep and it is likely that you are going to have to feed them either at mating or before lambing.

When you have to feed, grain legume supplements are by far the best however availability and price will determine which you use.

Suggested minimum weight profiles for ewe lambs and 1.5yr old ewe lambs.





At lambing we have had very little problem with difficult births. The ewes on their first lamb are also very nervous, for these two reasons we recommend minimal interruption to the ewes over lambing.

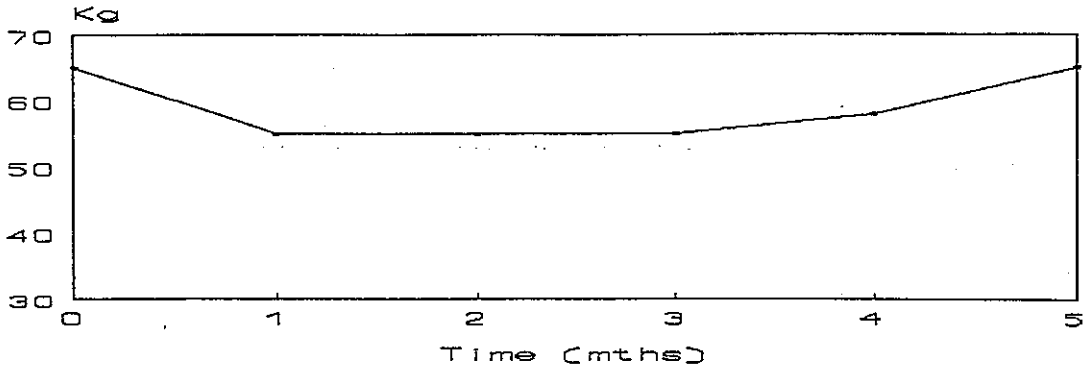
Time of Mating

Young ewes have a shorter breeding season than older ewes. This means that they will not cycle as early in the season. Ewe lambs can be mated from mid December on if they are of adequate weight and gaining weight over mating. One and a half year olds can be mated from the beginning of December on. If you try and breed them earlier than this you will have very variable results. Sometimes it will work sometimes not.

Management of Mature Ewes

Mature ewes should be heavier and therefore have greater body reserves than younger ewes. Over mating they can cope with some liveweight loss. It should not be necessary to supplement them over mating unless conditions are quite severe. They can also handle losing some weight in mid pregnancy. The important thing is that they should not be allowed to drop below condition score 2 at any stage and this means about a liveweight of 55kgs.

They will always need to be gaining weight in the last six weeks of pregnancy to achieve high birth weights and hence high lamb survival unless they are above 65kg. The worst thing you can do is have them losing weight rapidly in late pregnancy. What your aim should be is to have twin births weights above 4kg. If you weigh 3 or 4 sets of twins you will see how close you have got to this aim. If you attain this goal you will achieve a survival rate of 95% for singles 85% for twins and 70% for triplets unless you have a bad fox problem.



Supplementary Feeding

When supplementary feeding on dry feed a high protein supplement such as beans or lupins should be fed. This is because if you feed cereal grains the sheep will stop eating the dry feed. If you feed the high protein supplements their intake of the dry feed will not be suppressed. If they are on green feed their protein requirements are likely to be met from the green feed and cereal grains can be used to meet the high energy needs of the ewes.

If you decide the ewes need supplementary feeding then it must be done at reasonable levels. Feeding any grain at less than 400gms per head per day is a waste of time.

Supplementary feeding when there is greater then 1500kgs of dry matter per hectare on a green pasture is also not necessary. This would occur when the pasture is above 3 inches high.

Time of Mating

Mature crossbred ewes are still quite seasonal in their breeding patterns. They can be mated as early as October but remember any mating before January is relying on the "ram effect". The ram effect is the stimulation of cyclicity brought about by the sudden introduction of males. If the ewes have been exposed to males or are running close to males they may not mate. Remember to keep ewes and rams separate until mating when joining early. The success of early mating will depend on body condition, time since weaning and separation from rams. As you mate later in the season you will gain about 10% in lambs born for each month you mate later after October up until about April. The time at which you decide to mate will be determined by the feed supply pattern you have available and your perception of the prices you will receive for lambs sold at different times of the year.

Weaning

Weaning is a very valuable strategy in high lambing percentage flocks where you should be aiming at having half the ewes rearing 2 or more lambs. Lambs can be weaned very successfully at liveweights over 15kg or six weeks after the last lamb has been born. If you wean multiple reared lambs and put them on the best available pasture they will grow as fast as singles. Their are efficiencies in management to be gained and you can produce more total lamb weight using this strategy than spreading your ewes and lambs over the whole farm where some mobs will be on pastures not conducive to good lamb growth. There is also the fact that putting grass through a ewe to produce milk to grow a lamb is an inefficient process.

Careful preparation of a clover dominant worm free pasture on which to wean lambs is an important part of managing high fecundity flocks.

Ultrasound Scanning

I can see no economic benefit from ultrasound scanning of Booroola crossbreds. This is because only 20% of the flock will not be bearing multiples. The rest of the flock will always have to be managed as multiple bearing ewes. The other factor is that the ewes will have to be scanned every year and if you have lambing at the correct time of the year which is when paddock feed is becoming available then you will only have to supplement in a few years.

Foxes

The biggest problem with high lambing percentage flocks is foxes. If you have Booroola crossbreds in an area with large number of foxes you will have a disaster. This can be overcome and has been overcome on one of our demonstration sites by the proper use of "Fox off" the new fox bait recently released on the market. If you have a fox problem don't be fooled. Killing 30-40 foxes will have no impact on fox numbers. Baiting on a large scale is the only thing which will control them.

Lambing Paddocks

The best lambing paddock you can have is a clear pasture about 6-8" in height or just high enough so that when the lamb sits down it is partially protected from the wind. The greatest losses in high lambing percentage flocks are from separation from the mother. Any impediment either physical or visual which stops the lamb seeing or following the mother will cause losses. Areas with lots of trees or bracken are likely to cause more problems than they solve.

Summary

* Booroola crossbreds well managed can lamb up to rates of 250%.
* The best feed for lamb survival is green grass followed by grain legumes ie lamb at the right time.
* Young ewes need special treatment at mating and lambing.
* Multiple bearing ewes must gain weight in late pregnancy.
* Weaning as a valuable strategy in high lambing percentage flocks.
* Foxes will get fat on high lambing flocks.
* Lambs must be able to see and follow their mothers to survive.

The guidelines summarised in this pamphlet are a synopsis of 4 years of experimental work conducted on Kybybolite and struan Research Centre as well as private properties. If you want more detail on the trial results which support these findings contact Colin Earl at Struan Research Centre (087) 647419.

(v) Success in achieving objectives

The success of projects such as DAS 27 must be measured in terms of uptake by the Prime Lamb Industry. Achievement of the stated milestones is secondary to this criteria. Many projects may satisfy their milestones while still making little impact on industry. DAS 27 has achieved its success through the placement of rams into the industry coupled with good performance of the progeny of these rams. This has resulted in complete clearance of rams at prices 1.5-2 times that of Border Leicesters, our main competitors. Over 400 Booroola Leicester rams have been sold in the area around Struan and the progeny of these rams have been sold at values higher than that of Border Leicester crossbred ewes. The success has resulted in many of our ram purchasers returning to purchase more rams. It is true to say that DAS 27 has made the Booroola Leicester well known in South Eastern South Australia. This area however makes up a very small portion of the Australian Prime Lamb producing industry. To broaden their impact we began selling rams into NSW at Wagga in 1994 and 1995 to enable producers in this region to monitor their performance. To date 70 rams have been sold into this region and the first ewes produced from them will be due to lamb next year. We would anticipate that their performance would stimulate further demand.

The Booroola Leicester ram supply is increasing each year with the establishment of daughter studs based on Struan genetics. In 1994 and 1995, 40 stud ewes have been sold each year and several other breeders have established studs by breeding up from Border Leicesters. It is anticipated that these studs will supply about 150 flock rams next year. The adoption of the Booroola Leicester by industry is limited by the number of rams available. It is however important not to try and increase the number of rams too rapidly but to keep supply and demand closely balanced. Prime Lamb Producers are slow to change their production systems and an oversupply and drop in prices for the rams would discourage breeders from becoming involved. This balance has been well managed to this point in time and has positioned the Booroola Leicester for a healthy future.

The research on the management of Booroola crossbreds has been well received as evidenced by their success on demonstration sites. Most producers using Booroola Crossbreds are lambing them at a time of increasing feed availability and supplementing when necessary. The few failures reported to me can be explained by either adverse conditions during the trial of lambing or in one instance, severe drought.

(vi) Impact on Meat and Livestock Industry

Present

At this time there would be approximately 1000 Booroola Leicester breeding ewes in South Australia and around 9000 Border Leicester ewes. This suggests that ewes have captured about 10% of the market over the last 5 years. This is quite significant in South Australia but insignificant in the context of the Australian lamb industry. It does however suggest what is possible and that other ram outlets are needed in the main prime lamb producing states.

Future

The objective of replacing 1/3 of the industry's crossbred ewe flock with Booroola Crossbreds on the basis of their success in South Australia, quite achievable. In 5 years time I would predict a growth of Booroola Leicester ewes in South Australia to 3000 or about 30% of the prime lamb mother market. Their progress in other states will be slow without some further effort by the MRC. The major impediment to their progress in NSW has been the unfortunate circumstances leading to the lack of release of rams from the CSIRO's program. I feel sure that had they been able to release a similar number of rams as Struan that the uptake of the Booroola Leicester in that state would be much further advanced.

To attain the benefit from the industry's investment in this project it will be necessary for the MRC to finance some further demonstration sites in major prime lamb producing areas in NSW and Victoria. These should be financed by the MRC and supervised by local Departmental advisers. They would not be costly to run, and they are very effective. We would provide every possible assistance in the establishment of these sites. My experience in selling Booroola rams into NSW has been very informative. Even after spending several thousand dollars on advertising in papers on TV and Radio and sending personal letters, very few prime lamb producers in NSW have heard of the Booroolas. Producers, like ourselves do not read or listen to things which they do not think relate to them. If however, a neighbour is using a new breed, everyone is watching to see how they perform. I might also add that the Meat Profit Days have provided a good promotional platform.

Summary

The achievement of 30% market share will be attained in South Australia within 5 years. Their uptake in other states will be quite slow without further industry support.

Conclusion and Recommendations

The MRC along with market forces has been responsible for significant change in the pattern of Prime Lamb Production.

The production of larger and leaner carcases and the use of Lambplan have increased markedly over the years of the MRC's lamb program. However, the actual efficiency of lamb meat production has probably decreased. This has been because of reduction in stocking rates and carrying lambs on for longer times to reach the heavier weights. In many cases people have sold lambs at heavier weights and at higher prices for a lower profitability. Analyses of prime lamb production systems by Botting and Associates in the South East region of South Australia clearly demonstrates this. I believe that this is the case across the rest of Australia.

The MRC's program was correct in its assessment that if we did not develop an export market based on large lean lambs it would not survive. The next step in the process is to assist producers to do this cost effectively. A fundamental component of this system has to be the highly fecund ewes. Getting multiple born lambs up to heavy weights within the growing season off pasture is the problem. Attainment of heavy weights by supplementation in most cases will be unprofitable. The most efficient means of achieving this goal is by encouraging the development of new attitudes by lamb producers. One of the most common reason people choose not to adopt multiple bearing ewes is that they correctly believe that they will not be able to produce the large lamb using them. A program to encourage partitioning of the production system into "producers" and "finishers" would do a lot to improve the overall efficiency of our lamb industry. This of course happens a lot anyway, but a program to convince producers that this was a legitimate and profitable concept would be very helpful.

The way to assist this development would be to employ an economist and a practical sheep researcher to develop extension material that demonstrates the financial advantages to individual producers from adopting this attitude. The data from Bottings clearly shows that in our region the most profitable producers are those that sell the most lambs not the highest priced lambs. Other regions such as the irrigation areas would be most profitable just doing fattening.

Summary

For the industry to achieve its greatest benefit from these highly fecund sheep some expenditure on changing the attitudes of our Prime Lamb Producers is warranted.

Administrative Details Report

Financial Report

Dennis O'Malley has provided regular financial reports to the MRC from DAS 27. His statement of funds by the MRC are as follows:

Financial History
Fund: Meat Research Corporation
Fund Code: DAS 027
Project Title: Booroola Gene
Supervisor: C Earl
Debit Code: TMSS-2M03

Financial Year	Expenditure			
	Salaries $	Operating $	Assets $	Total $
1991/92	17,987.60	27,003.21	539.00	45,529.81
1992/93	35,395.25	54,429.40	4,128.65	93,953.30
1993/94	36,388.27	56,414.27		92,802.54
1994/95 (Dec)	18,540.33	17,700.55		35,240.88
Total	108,311.45	154,547.43	4,667.65	267,526.53
1994/95 (May)				
Total	108,311.45	154,547.43	4,667.65	267,526.53

Funds supplied by the research organisation

The research organisation has supplied 0.4 of a research officers time to the project as well as the resources to multiply the flock. The value of the research officers time would amount to approximately $100,000 over the life of the project. The value of resources would have been met from proceeds from the project.

Intellectual property arising from the project

There was no saleable intellectual property developed in DAS 27.

Commercial exploitation of the project

Females from the Booroola flock have been sold to private producers who are beginning to sell rams. The entire breeding nucleus will be sold in december 1996.