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Optimising reproduction in the Dorper ewe through nutrition

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Abstract

This study comprised two experiments aimed at increasing the reproductive performance of Dorper ewes. Experiment 1 investigated the effect of ewe liveweight at joining, liveweight change and supplementary feeding with lupins on fertility and conception rate of Dorpers. Experiment 2 was aimed at optimising lamb birthweight for high lamb survival and assessed the impact of ewe liveweight profile over pregnancy and lactation on the birthweight and weaning weight of the lamb. Experiment 1 found that fertility (ewes pregnant/ewes mated) and conception rate (lambs scanned/ewes mated) increased with increased liveweight at joining and liveweight change pre and early joining. Providing a 200g/h/d lupin supplement for 3 weeks (2 weeks prior to joining and during the first week of joining) increased fertility by 7% and increased conception rate by around 18%. A higher supplementation rate of 500g/h/d for 2 weeks also increased fertility but did not increase conception and also caused the ewes to lose weight. Experiment 2 found that the optimal birthweight of Doper lambs are 4-6 kg for high survival rates (90%). Birthweight of lambs can be predicted by ewe liveweight at joining, ewe weight change during pregnancy, sex and birth-type of the lamb (single or twin). Weaning weight is also influenced by these factors as well as the weight change of the ewe during lactation. These effects are similar to those seen in Merinos. Producers can use these relationships to determine cost-effective feeding strategies for their Dorper ewes to maximise reproductive rates.

Executive summary

Dorper ewes have the capacity to produce quality lambs year-round to supply both international and domestic sheepmeat markets. However, there is little information available to producers on how to optimise reproductive rates of Dorper ewes and it is unknown whether current recommendations for Merinos are applicable to other breeds of sheep such as the Dorper. The two phases of reproduction that are the most critical to increasing reproductive rates are joining for maximum conception of lambs, and late pregnancy and lactation for maximum survival and growth rates of lambs. This study comprises two experiments, experiment 1 looks at the drivers behind improved fertility and conception rate in Dorpers and experiment 2 investigates the relationship between ewe liveweight profile during pregnancy and lactation on the birthweight, weaning weight, growth rate and survival of Dorper lambs.

To investigate drivers for high conception rate and fertility in experiment 1, 650 Dorper ewes of mixed age were grazed on wheat stubble during summer and fed 2 different supplement levels; 500g/h/d of lupins for the week before and first week of joining or a lower amount of supplement of 200g/h/d of lupins but for a longer time period of 2 weeks before and the first week of joining. These treatments were compared to control ewes that received no supplementation. Feeding Liveweight, liveweight change over the supplementation period and condition score were measured pre joining, at the start of joining and at the end of the 5 week joining period.

Supplementing ewes with 200g/h/d of lupins two weeks before and in the first week of joining increased fertility by 7% (ewes pregnant/ewes mated) and conception rates by 18% (lambs scanned/ewes mated). Heavier ewes at joining had higher fertility and conception rate. Ewes that gained weight in early joining (two weeks prior to and the first week of joining) also had a higher fertility and conception rate. Supplementing ewes with 500g/h/d increases fertility of ewes but did not increase conception. This high level of lupin feeding also causes ewes to lose weight and condition so is not recommended for Dorper ewes. Predictions for optimum conception show that ewes should be 60 kg (or more) liveweight and condition score 3 and above at joining, be on a rising plane of nutrition and be fed 200g/h/d of lupins for the two weeks prior to and the first week of joining when mating in summer.

The influence of the liveweight profile of the ewe during late pregnancy and lactation on the birthweight, weaning weight, growth and survival of the lamb was investigated in experiment 2. To obtain different liveweight profiles of the ewes, 270 single-bearing ewes and 90 twin-bearing ewes were supplementary fed to either maintain weight or lose weight during late pregnancy (day 90 to lambing, target weight loss of -5kg) and early lactation (lambing to day 63 of lactation, target weight loss -2kg). Ewe liveweight profiles during pregnancy and lactation were regressed against birthweight and weaning weight of lambs to establish relationships between these parameters at different stages of reproduction. The relationship between birthweight and lamb survival was also investigated.

Birthweight of the lamb is positively influenced by the liveweight of the ewe at joining and her liveweight change during pregnancy. Ewe liveweight change in both early to mid and late pregnancy influenced birthweight to similar degrees. Optimal birthweights of Dorper lambs are around 4-6 kg with survival rates dropping below 80% with birthweight of 3.5kg and lower. Weaning weight is also influenced by joining weight and ewe weight change over pregnancy as well as the ewe’s liveweight change during lactation. The experiment also found that the condition score of Dorper ewes was less sensitive to changes in ewe liveweight than Merinos.

The relationship of ewe liveweight change and joining weight to lamb birthweight and weaning weights are similar for Dorpers as they are in Merinos, as is the optimum birthweight for lamb survival. Therefore, nutritional recommendations for the optimum liveweight profile of Merino ewes can be broadly supplied to Dorpers with two considerations. First, producers should follow the lifetime wool guidelines for liveweight change rather than condition score as the relationship between the two is different for Dorper ewes. Second, the recommendations for Merinos (Lifetime wool guidelines) are for spring lambing ewes, when Dorper ewes are lambing at other times of the year farmers can use the predictions in this experiment combined with current feed costs to calculate the most economical liveweight profile of the ewe.

Overall, the results from both experiments show that the nutrition of Dorper ewes needs to be managed during each phase reproduction to reach their production potential. Dorper ewes should have high joining weights (60kg+) and producers can use the predictions in these experiments to find the most cost-effective use of feed resources for their Dorper flock when lambing at different times of the year.

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1. Background

Due to its favourable meat quality, rapid lamb growth rates and unseasonal breeding, the Dorper breed has the capacity to produce large numbers of quality lambs for international and domestic markets year-round. In order for Dorpers to reach their high potential for lamb production, their reproductive rates must be maximised though optimal nutrition of the ewe. It is essential to understand the effect of nutrition during the two phases of reproduction that are crucial to achieving high lamb production, these being joining and during late pregnancy and lactation. Nutrition during joining needs to be optimised for high fertility and conception rates whereas nutrition during late pregnancy and lactation is intrinsically linked to lamb survival and growth rates. This is also the period where the feed requirements of the ewe are highest and for many sheep farmers, supplementary feeding of ewes during this time is a major cost of production. Therefore, it is imperative that the ewe is fed cost-effectively whereby feed costs are minimised but lamb survival and growth rate is not compromised.

A literature review funded by MLA found very limited information on manipulating nutrition of the Dorper ewe to maximise reproductive rates (Chadwick and Pearce, 2012). The optimum condition score and nutrition for Merino ewes during reproduction in Australia has been established (Thompson et.al., 2011, Oldham et.al., 2011), however, applying this system to Dorper ewes has been shown to cause reproductive wastage through high lamb mortalities (Kilminster and Greeff, 2011). The overall aim of this project is to improve the understanding of the impact of ewe liveweight and condition score change on the performance of Dorper ewes and their progeny thus improving ewe reproductive rates and progeny survival and growth. This study comprises two experiments, experiment 1 looks at the drivers behind improved fertility and conception rate in Dorpers and experiment 2 investigates the relationship between ewe liveweight change during pregnancy and lactation on the birthweight, weaning weight, growth rate and survival of Dorper lambs.

2. Project objectives

By 31st March 2015:

1. Assess the impact of ewe condition score and supplementary lupin feeding strategies pre and early post-joining on conception rates of Dorper ewes over a range of age classes (Experiment 1)
2. Assess the impact of ewe nutrition and changes in weight and condition score during late pregnancy and/or early lactation on lamb survival, growth and success of future joining (Experiment 2).
3. Utilised findings from Experiments 1 and 2 to develop guidelines to optimise Dorper ewe and progeny performance by assisting producers to optimise condition score and feed resources for increased reproductive performance in a polyoestrous mating scenario.

3. Experiment 1

3.1. Introduction

To increase reproductive rates of Dorper sheep, nutrition around the time of joining needs to be optimised for maximum conception rates. There is limited information on the influence of liveweight, liveweight change and supplementation at joining on the fertility and conception rate of Dorpers or any other breed that is managed in a polyoestrus mating scenario. Data from Basson et.al, (1969) indicated that increasing nutrition at joining in Dorper ewes may increase weaning percentages. Other studies have shown that joining body weight does not influence fertility in Dorpers (ewes lambing per ewe mated) (Schoeman and Burger, 1992) however it may increase the rate of multiple births (Cloete and De Villers, 1987). In other breeds of sheep, a higher liveweight and increasing plane of nutrition has been found to increase ovulation rates (Gunn et al., 1969; Nottle et al., 1997; Viñoles et al., 2009). Ovulation rates have also been found to increase when sheep are supplementary feed lupins for short period of time pre-joining, possibly due to increases in the digestion of protein post-ruminally (Nottle, 1988). In Merinos, feeding 500 grams per head per day of lupins for 14 days at the start of joining increases fertility and fecundity of ewes (Nottle et al., 1997). However, the response to lupin supplementation in Merinos has been variable and there are conflicting results of the influence previous nutrition in Merino ewes (Croker et al., 1985; Nottle, 1997; Pearse et al., 1994). Breed of the ewe may also effect the response of fertility and conception rate to supplementation as more fertile breeds may be more responsive to nutrition at joining (Lassoued et al., 2004). With Dorper ewes mating every 8 months, there is limited time between reproductive cycles for ewes to regain liveweight so increasing nutrition at joining may be an important element in increasing reproductive rates.

This study investigates the influences of liveweight, liveweight change and lupin supplementation on the fertility and conception rate of Dorper ewes. The lupin supplementation rates used are 500 grams per head per day for two weeks (7 days prior to joining and the first 7 days of joining) which has been recommended for Merinos (DAFWA, 2008). A lower supplementation rate of 200 grams per head per day for a longer period of three weeks (14 days pre-joining and the first 7 days of joining) was also included in the study to test if a more moderate increase in nutrition would influence reproductive success.

3.2. Methodology

Experiment 1 used 650 ewes of mixed age but mostly between 1.5- 5 years old including 44 maiden ewes which were 1.5 years old and above 45kg liveweight.
All ewes grazed similar wheat stubbles in three different 55 hectare paddocks. Ewes were divided into 3 different feeding regimes. No replicates were used in this study.

- *Group 1:* Un-supplemented
- *Group 2:* 200g/h/d of lupins for 3 weeks - 14 days before joining and the first 7 days of joining.
- *Group 3:* 500g/h/d of lupins for 2 weeks - 7 days before and the first 7 days of joining.

Ewes were weighed and condition scored a month before joining as well as pre and post feeding treatments (-2 and 1 week) and at the end of joining (5 weeks).Figure 1 below shows the timing of feeding treatment.

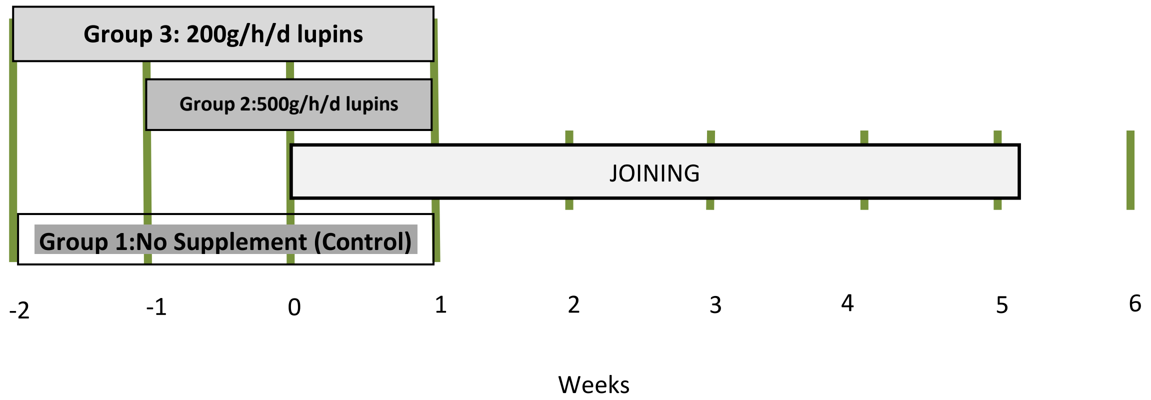


Figure 1: Timing of feeding regimes for each treatment group

The Dorper ewes were run in a commercial flock that was managed so ewes were lambing approximately every 8-9 months. Results of the previous pregnancy scanning were recorded. Lambs from the previous mating had been weaned 4 weeks before this joining. Dorper rams were joined to ewes at 3% for a period of 5 weeks. Ewes were pregnancy scanned at day 45 of gestation to distinguish the ewes that conceived during the first 20 days of joining. This selection was done to have a tighter lambing timeframe in Experiment 2. Ewes were scanned again at day 75 of gestation to determine conception rate for the whole of joining.

Diet

Prior to the experiment ewes were grazing dry wheat stubbles (wheat crop residue) as one mob. When the different supplementary feeding regimes started ewes were separated into three different paddocks of similar wheat stubble, each 55 hectares. Food on offer (FOO) in the three paddocks was assessed by collecting all plant material in a 33cm square quadrat and repeated at 15 different places in the paddock. The plant material was sorted into 2 components; preferred, which sheep would be selecting and consuming and non-preferred which sheep were unlikely to select. Preferred components were leaf material, chaff and "whiteheads" which are the outer casings of the wheat head that contain the grain before the grain is extracted by the harvester. These components have the highest digestibly, metabolisable energy and protein content so the sheep select these as they are grazing. Non-preferred components are the hard lower stalks of the plant that are high in lignin and are less digestible so the sheep are unlikely to select these when the preferred elements of the stubble are available. We expect that the ewes consumed only the preferred components of the wheat stubble during the experiment. FOO and its nutritional value were very similar in the three paddocks and averages are shown in Table 1. It is estimated that the FOO in the wheat stubbles were enough to maintain the liveweight of the ewes without supplementary feeding (control ewes). The lupins were fed daily via a trail feeder.

Table 1: Components of the ewe's diets and their average nutritional content expressed on a dry matter basis. FOO (food on offer), DM (dry matter), ADF (acid detergent fibre), DDM (digestible dry matter), ME (metabolisable energy), CP (crude protein), WSC (water soluble carbohydrate), NDF (Neutral detergent fibre). Wheat stubble (crop residue) was separated into components that would be preferred and selected by sheep (leaf matter, outer casing of wheat head after grain removal "whiteheads") and those non-preferred components that would not be selected such as hard stem stalks.

Diet Component	FOO (Kg DM/Ha)	% DM	% ADF	% DDM	MJ/Kg ME	% CP	% WSC	% NDF
Lupin grain		92.3	19.0	94.1	14.1	36.9	--	--
Wheat Stubble:								
Preferred	2000	91.0	47.0	52.7	7.4	3.5	4.5	76.1
Non-preferred	1200	91.0	55.5	41.4	5.4	1.1	2.4	86.4

Statistical analysis

All ewe liveweights and condition scores were analysed by one-way analysis of variance (ANOVA) for supplement treatments effects only. The analysis of ewe conception rate was examined by restricted maximum likelihood method (REML) with supplement treatments, ewe liveweight at 2 weeks prior to joining, ewe liveweight change for the period from 2 weeks prior to joining to the end of supplement treatments, ewe age, previous pregnancy scan and interactions thereof, where appropriate, as fixed effects. The effects of ewe age, previous pregnancy scan results, supplement treatments, ewe liveweight at 2 weeks prior to joining and ewe liveweight change for the period from 2 weeks prior to joining to end of supplement treatments on the fertility of ewes was analysed by generalised linear model with a binomial distribution and a logit link function. For all analyses, where appropriate, terms were included only if they were statistically significant (P < 0.05). All statistical analyses were performed using GenStat (VSN International 2012).

3.3. Results

Fertility

Supplementary feeding with lupins (either 200g or 500g/h/d) increased the fertility of the ewes by round 7% (ewes pregnant/ewe mated)(P<0.05)(Table 2). There was no difference in fertility between feeding 200g/h/d and 500g/h/d of lupins as these treatments had a similar fertility at around 89% compared to the unsupplemented control at 82%.

Age also influenced fertility with young ewes at 2 years of age being more fertile then old ewes at 5 years of age (P<0.05) with the other age groups being in-between. Previous pregnancy scan results (for last mating) did not influence fertility (P>0.05).

Table 2: Fertility (ewes pregnant/ewes mated) predictions and approximate standard errors thereof.

Term	Fertility (%)	Standard error*
Age		
2	91.3[a]	1.59
3	87.7[ab]	2.73
4	79.7[ab]	6.38
5	81.0[b]	4.94
Group		
Control	82.2[a]	2.6
200g/h/d	89.4[b]	2.2
500g/h/d	89.3[b]	2.1

*Standard errors are only approximate due to the analysis method used.
[ab] Significantly different (P<0.05)

Liveweight and liveweight change over the joining periods also influenced fertility. Ewes that were heavier 2 weeks before joining and gained liveweight over the supplementation period (-2 weeks and 1 week joining) had a higher fertility (P<0.05)(Table 3). For the analysis, ewe age was truncated with ewes age 5 years and above included as one age group (5 year olds) due to minimal numbers. There was a significant treatment, ewe age, liveweight 2 weeks before joining and liveweight change over the supplement period effect on fertility (P<0.05), but no effect of the ewe previous pregnancy scan or any interaction of terms fitted.

Table 3: Fertility predictions (ewes pregnant/ewe mated percentage) for supplement treatments at different levels of liveweight 2 weeks before joining, kg, (LW2) and supplementation period liveweight change, kg, (LWC) averaged for ewe age.

LWC	LW2	Control	200kg/d/hd	500kg/d/hd
-5	45	58.1	75	78
-5	50	68	82.2	84.5
-5	55	76.5	87.6	89.3
-5	60	83.4	91.6	92.8
-2	45	67.6	81.9	84.2
-2	50	76.1	87.4	89.1
-2	55	83.1	91.5	92.7
-2	60	88.3	94.3	95.1
0	45	73.2	85.6	87.5
0	50	80.7	90.1	91.5
0	55	86.6	93.4	94.4
0	60	90.9	95.6	96.3
2	45	78.2	88.6	90.2
2	50	84.6	92.3	93.4
2	55	89.5	94.9	95.7
2	60	92.9	96.7	97.2
5	45	84.4	92.2	93.3
5	50	89.3	94.8	95.6
5	55	92.8	96.6	97.1
5	60	95.2	97.8	98.1

Conception rate

Conception rate (lambs scanned/ewe mated) was increased by supplementary feeding ewes 200g/h/d of lupins compared to control (P<0.05). Feeding 500g/h/d was in-between these values and was not significantly different to the control or the 200g/h/d supplementation group (P>0.05) (Table 4).

Table 4: Effect of supplementary treatments on conception rate

Treatment	Conception rate (%)
Control	93.1[a]
200g/h/d	110.9[b]
500g/h/d	102.9[ab]
l.s.d (P=0.05)	10.31

Similar to fertility, conception rate also increased with a higher liveweight two weeks before joining and an increasing liveweight change in the two weeks before and first week of joining (P<0.05). Table 5 shows predictions on how these factors influence conception rate for each rate of supplementary feeding. There was no effect on conception rate of ewe age, the pregnancy scan results of the previous mating period or any interaction of terms fitted.

Table 5: Conception rate predictions (lambs scanned/ewe mated percentage) for supplement treatments at different levels of liveweight 2 week before joining, kg, (LW2) and supplementation period liveweight change, kg, (LWC).

LWC	LW2	Control	200kg/d/hd	500kg/d/hd
-5	45	67.2	88	82.1
-5	50	76.1	96.8	90.9
-5	55	84.9	105.7	99.8
-5	60	93.8	114.5	108.6
-2	45	75.2	95.9	90
-2	50	84	104.8	98.9
-2	55	92.9	113.6	107.7
-2	60	101.7	122.5	116.5
0	45	80.5	101.2	95.3
0	50	89.3	110.1	104.2
0	55	98.2	118.9	113
0	60	107	127.8	121.8
2	45	85.8	106.5	100.6
2	50	94.6	115.4	109.5
2	55	103.5	124.2	118.3
2	60	112.3	133.1	127.1
5	45	93.7	114.5	108.6
5	50	102.6	123.3	117.4
5	55	111.4	132.2	126.2
5	60	120.3	141	135.1

Liveweight and condition scores

Ewes were around 52 kg two weeks before joining and liveweights ranged from 40kg to 73kg. The three nutritional treatment groups were similar liveweight before supplementation began but after the first week of joining when the 3 weeks of supplementation finished, the ewes fed 500g/h/d of lupins were lighter than the other two groups of control and ewes fed 200g/h/d (P<0.001) who were similar liveweights (Table 5). The 500g/h/d treatment continued to be lighter than the other two groups at 5 and 10 weeks post-joining (P<0.05). The 200g/h/d group remained a similar liveweight to the controls until 10 weeks post joining when they were heavier than control ewes (P<0.05). Over the supplementation period (-2 weeks to +1 week of joining) there were differences in liveweight change between the three groups. The 500g/h/d ewes lost weight (-1.68kg), the 200g/h/d group lost a small amount of weight (-0.24kg) whereas the control ewes gained weight (0.57 kg) (P<0.05).

The ewes fed 500g/h/d of lupins also had a lower condition score compared to the other two groups after the supplementation period finished (P<0.05) (Table 6). However, by 5 weeks and 10 weeks after joining they were a similar condition score to the control ewes. The ewes fed 200g/h/d had a higher condition score than the control and the 500g/h/d groups both 5 weeks and 10 weeks after joining (P<0.05).

Table 6: Effect of supplementary treatments on condition score and ewe liveweight (kg), for various measurement times as well as liveweight change (kg) over the supplementation period (between 2 weeks pre-joining and 1 week post joining).

Measurement	Control	200 g/h/d	500 g/h/d	L.S.D [A] (P=0.05)	Significance[B]
Condition score					
4 weeks pre joining	2.88	2.90	2.89	0.072	n.s.
1 week post joining	2.96[a]	2.97[a]	2.88[b]	0.075	P<0.05
5 weeks post joining	3.07[a]	3.15[b]	3.03[a]	0.071	P<0.01
10 weeks post joining	3.02[a]	3.09[b]	2.98[a]	0.065	P<0.01
Liveweight					
4 weeks pre joining	54.8	54.8	54.3	1.28	n.s.
2 weeks pre joining	52.1	51.9	51.7	1.20	n.s.
1 week post joining	52.8[a]	51.6[a]	49.9[b]	1.24	P<0.001
5 weeks post joining	55.0[a]	55.9[a]	53.5[b]	1.16	P<0.001
10 weeks post joining	52.4[a]	53.7[b]	51.1[c]	1.13	P<0.001
Liveweight change over supplementation period [C]	0.571[a]	-0.236[b]	-1.684[c]	0.5090	P<0.001

[A] Maximum least significant difference covering all possible comparisons.
[B] P value for F ratio, n.s. is P>0.05.
[C] Note that not all animals had weights at 2 weeks before or 1 week post and so LWC values will be different (629 animals at 2weeks before, 595 at 1 week post and 591 for LWC).
[ab] Indicates significance P≤0.05

3.4. Discussion

Feeding 200g/h/d of lupins to Dorper ewes from 2 weeks pre-joining to 1 week post joining can increase fertility and conception rate. This relatively low amount of supplementary feed above maintenance requirements increased conception rates by nearly 18% and fertility by 7% above the unsupplemented controls. Higher liveweights near joining and liveweight gain in the two weeks prior to and first week of joining also increased fertility and conception rates in Dorpers.

The lupin supplement may have increased fertility and conception rate due to an increase in ovulation rate. An increase in ovulation rate through supplementation of lupins is well documented in Merinos (Lightfoot, 1976; Nottle, 1997; Nottle et al., 1997; Parr, 1992; Pearse et al., 1994) so it is likely that this also occurred in Dorper ewes. The lupin supplement may have increased the amount of protein that was digested post-ruminally which has been found to increase ovulation rate (Nottle, 1988). Metabolic hormones such as insulin and leptin are altered by the supplementation and this may influence reproductive hormones such as follicle stimulating hormone (FSH) to increase ovulation rate which may in turn increase fertility and conception rate (Viñoles et al., 2010). However, in Merinos results from on-farm trials on the reproductive gains from the 500g/h/d feeding regime has been mixed with some studies showing an increase in fertility and fecundity (Nottle et al., 1997) and others concluding the response is too variable to recommend (Croker et al., 1985). This variability may be due to differences in body condition of the ewe and previous nutrition which has been shown to influence the response to lupin supplementation (Nottle, 1988; Viñoles et al., 2010). Therefore, further on-farm trials should be conducted with Dorpers to ensure a consistent response to lupin supplementation, particularly when mating at different times of the year when different pasture quality and quantity is available.

Higher liveweight and more liveweight gain pre and early joining also increased fertility and conception rate. This agrees with a previous study on Dorpers that found conception rate increases linearly with increased liveweight at joining (Cloete and De Villers, 1987). However, Cloete and De Villers (1987) did not see the same increase in fertility with increased liveweight at joining found in the present experiment and nor did another South African study who found the two were unrelated (Schoeman and Burger, 1992). However both studies had high average joining weights of 61kg (Schoeman and Burger, 1992) and 72kg (Cloete and De Villers, 1987) whereas in the current study, ewes were only and average of 52kg at joining. It is likely that the reproductive response to higher liveweight at joining is much stronger with the lower average joining weights in our study. The reproductive response shown in Dorpers to liveweight at joining is similar to that found in Merinos (Ferguson et al., 2011; Lindsay, 1975) as well as other breeds (Kenyon et al., 2004; Morley F.H.W., 1978). A one kilogram increase in Dorper ewe liveweight at joining corresponds to around 2 extra foetuses per 100 ewes, which is similar to Merinos (Ferguson et al., 2011). Increasing liveweight pre and early mating also increased fertility and conception which has also been found by others (Gunn and Maxwell, 1989). In polyoestrus mating senarios where there is only a short period of time between weaning lambs and joining, it is important for ewes to be in high liveweights (60 kg and above) and on an increasing plane of nutrition for maximum fertility and conception.

The small amount of weight loss of the ewes fed 200g/h/d may have been influenced by gut-fill. Over the supplementation period, the ewes fed 200g/h/d lost a small amount of weight (-0.2kg) whereas the control ewes gained weight (0.5kg). This weight change might be due to a substitution effect whereby the ewes where grazing less roughage because they were consuming lupins so a lower gut fill could account for the weight change in the short term. This theory is supported by the fact after the supplement finished and all ewes were on the same diet the 200g/h/d ewes had a similar liveweight to controls and at 10 weeks post-joining had a higher liveweight. This indicates the supplement had a beneficial effect over the longer term even if the short term benefits may have been masked by differences in gut fill.

Feeding 500g/h/d of lupins seems to be of detriment to Dorpers as they lost liveweight and were still lighter than the other groups 9 weeks after the supplementation stopped. This weight loss could be because the ewes where using the lupins as a substitute for grazing rather than a supplement which led to them having a decreased energy intake overall resulting in weight loss. This has been shown in Merino wethers when given a 500g/h/d lupin supplement but, these wethers were supplemented for a much longer period of 143 days (Thompson, 1990). In studies where Merino ewes are supplemented with 500g/h/d/ of lupins for 2 weeks as in the current study, there are have been no reports of weight loss in ewes (Nottle et al., 1997; Viñoles et al., 2012). This inconstancy with the current study may be because of differences between Merinos and Dorpers in the way they handle excess nitrogen. Although Dorpers have been found to have similar nitrogen requirements to other breeds (Degen and Kam, 1991), other studies have shown that there may be differences in nitrogen retention between breeds. Semi-arid hair lambs (Santa Inês) retained around 35% more nitrogen than temperate wool lambs (Ideal x Ile de France) when the level of roughage in the diet was around 40% and had a higher digestibility of crude protein (Silva et al., 2004). A further study showed that the hair lambs were more efficient at protein utilization than wool lambs (Silva et al., 2007). Dorpers may be similar to these hair sheep or goats who recycle urea more efficiently to cope with droughts in their desert environments (Silanikove, 2000). If Dorpers retain more nitrogen then consuming high amounts of protein rich foods such as lupins may mean that the excess ammonia needs to be converted to urea which is an energy cost to the animal. This energy cost could contribute to the weight loss. In addition to this, the high amounts of concentrate in the diet would have caused a reduction in roughage intake and an imbalance of fibre and concentrate altering rumen function. Although the exact cause of this observed weight loss is unclear, feeding Dorpers high amounts of lupins, (500g/h/d+) should be avoided.

Increasing ewe liveweight change increased fertility and conception however both lupin supplements caused an average loss in liveweight yet they still had a positive effect on fertility. These two influences are conflicting which may help to explain why the smaller amount of lupin supplementation (200g/h/d) had a greater effect on conception than the 500g/h/d supplement. The smaller amount of supplement may have been enough to increase post-ruminal protein digestion to increase fertility and conception (Nottle, 1988) but not such a large amount so as to cause the weight loss seen in the ewes fed 500g/h/d which would have negatively affected conception rate. Feeding ewes 200g/h/d of lupins seems to provide the metabolic responses required for increased ovulation coupled with an increased weight gain in the long term to increase fertility and conception rate.

Overall, the lower amount of supplement provided a better response in reproductive rate. The 200g/h/d group received a total of 4.5kg/head over the supplementation period versus 7kg/h/d for the 500g/h/d group. Therefore, it is recommended that Dorper ewes grazing dry pasture or stubble should be supplemented with 200g/h/d 2 weeks prior to and in the first week of joining to increase fertility and conception rates. Also the ewes should have high liveweights (60kg +) and be on an increasing plane of nutrition at joining. More research needs to be conducted of the variability of the supplementation response under different grazing conditions (i.e. winter or spring).

4. Experiment 2

4.1 Introduction

Reproductive rates in Dorper flocks need to be optimised to increase profits to farmers but there is little information specific to this breed on how the nutrition of the ewe during pregnancy and lactation influences lamb production. A key indicator of reproductive success is the birthweight of the lamb as it has a major impact on lamb survival (Atkins, 1980; Knight, 1988; Oldham et al., 2011). Weaning weight is also an important economic trait as it influences survival after weaning (Campbell, 2009) and for meat breeds such as the Dorper, higher weaning weights mean decreased time to slaughter. In Merinos, birthweight can be predicted by ewe liveweight at joining and changes in ewe liveweight during pregnancy (Oldham et al., 2011). These factors also predict weaning weights in Merinos, however, nutrition of the ewe during lactation has the largest effect on weaning weights (Thompson et al., 2011). Other studies on Merinos have also found similar interactions between ewe liveweight during pregnancy and lamb birthweight and survival (Kelly, 1992). Based on this research, the optimal liveweight profile of the Merino ewe in southern Australia is to join ewes at 90% of the standard reference weight for the genotype (45-50 kg), ewes can lose a small amount of weight (around 3 kg) after joining but this weight needs to be regained by lambing (Young et al., 2011). These relationships have been well tested and established on Merinos and they may also apply to Merino ewes mated to terminal sires (Poll Dorset or Suffolk), and Merino cross Border Leicester ewes mated to Merinos (Paganoni et al., 2014). However, we need to establish that a similar relationship occurs in Dorpers before these feeding recommendations can apply to Dorper producers.

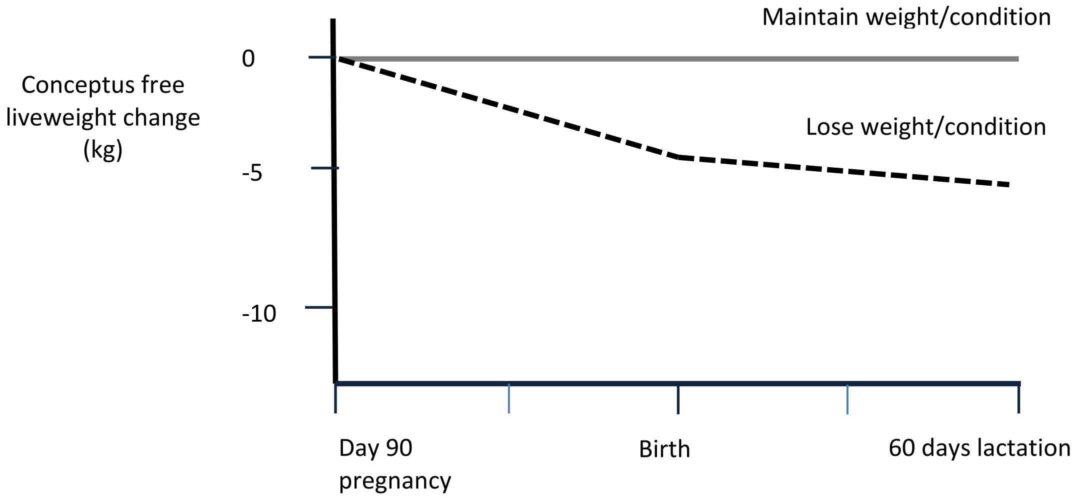
There is some evidence to suggest that Dorper ewes may be different from Merinos in their optimum nutrition during pregnancy. When Dorper ewes were run with Merino ewes and managed according to the optimal liveweight profile of the Merino ewe, there was a high lamb mortality rate of 23-27% from birth until weaning in the Dorper lambs (Kilminster and Greeff, 2011). This suggests that nutrition that is optimal for Merinos, may not be so for Dorpers. Other studies have also indicated there may be breed differences in the influence of ewe nutrition on lamb production parameters (Brand and Franck, 2000). Dorper ewes have been shown to utilise more body reserves than Merinos ewes during pregnancy and lactation (Basson et al., 1969; De Waal and Biel, 1989). Decreases in energy intake during lactation has a large impact on weaning weight in Merinos (Thompson et al., 2011) but the impact does not seem to be as large in Dorpers (Joubert, 1972). As Dorpers are hair sheep, they do not have to partition nutrients towards wool like Merinos which may mean that when utilising body reserves, more can be partitioned towards reproduction (De Waal and Biel, 1989). These studies show that although there may be breed differences in nutrient partitioning, there is still a strong relationship between ewe nutrition and lamb production parameters in Dorpers. Therefore, we hypothesise that birthweight and weaning weight of Dorper lambs will be influenced by ewe liveweight and liveweight change during pregnancy and lactation.

4.2 Materials and methods

The trial was conducted on a commercial Dorper farm in South-west Western Australia near Wickepin which experiences a Mediterranean climate. Ewes where joined in late January and lambed in June.

Dorper ewes (360) in condition score 3 of mixed age were selected for the trial. All the ewes had previously lambed (no maiden ewes) and were scanned as conceiving in the first 20 days of joining. Pregnancy status of ewes, 90 twin bearing ewes and 270 single bearing ewes, were combined in a factorial arrangement with 2 nutritional treatments, maintain condition and lose condition. With two replicates of each combination (pregnancy status by nutritional treatment) this resulted in 8 plots in a randomised block design (2 blocks of 4 plots).

The target conceptus-free weight loss was 5kg during pregnancy and a further 2 kg during lactation. The figure below shows the targeted liveweight change.



Measurements

Ewes were weighed and condition scored weekly during pregnancy and fortnightly during lactation. These weights and condition scores were then used to adjust the supplementary feeding rates of the ewes to help achieve the required condition score targets. All liveweights were corrected for the weight of the feutus using the equation by Wheeler (1971) and calculated back from the exact date of birth of the lamb.

Birthweights of lambs were taken within 24 hours of birth while marking weight was at approximately 3 weeks of age. Lambs were again weighed at the conclusion of experimental treatments (approximately 8 weeks of age), at weaning (12 weeks of age) and then monthly until they reached 11 months of age.

After weaning the ewes were grazed on pasture for 3 weeks before rams were placed with the mob for a 5 week joining. The scanning results of the ewes were also recorded to test any residual effects of the nutritional treatments on subsequent joining.

Feeding regime

Prior to the experiment commencing ewes grazed dry wheat stubble and were supplementary fed with hay until day 90 of pregnancy when the nutritional treatments started.

During the experiment ewes grazed on wheat stubble that had been dry sown to wheat and canola with a disc seeder. Stocking rate was approximately 8.5 ewes/ha with twin bearing ewes grazing on approximately 2.7 ha plots and single bearing ewes grazing on approximately 7.8 hectare plots. Feed on offer (FOO) was measured fortnightly. However, high stocking rates, low pasture base and low rainfall meant that pasture only provided a very small amount of nutrient requirements (estimated around 2 MJ/kg DM metabolisable energy). FOO was mainly very low quality dry stubble and green pasture did not make up a significant portion of the diet until mid lactation. Since the FOO was comprised of hard weathered crop stalks that sheep would not select, FOO was sorted into “preferred” and “unpreferred” to show the components that the sheep would have consumed (see methods of experiment 1 for nutrient composition of “not preferred”) (Table 7).

Table 7: Total food on offer (FOO) of all plant material available on plots at different dates and stages of pregnancy and lactation (Preg/Lact). The green proportion of the FOO is also shown as well as the percentage of the FOO that was preferred by sheep (softer dry leaf material, not hard stalks). Values are averages of the 2 replicate plots for twin lose ewes (TL), twin maintain (TM), single maintain (SM) and single lose (SL).

Date	Day Preg/Lact	Total FOO (All plant material) (kg DM/ha)				Estimated FOO of green pasture (kg DM/ha)				% of preferred FOO to all available FOO			
		TL	*TM*	*SM*	*SL*	*TL*	*TM*	*SM*	*SL*	*TL*	*TM*	*SM*	*SL*
28 May	120	2450	2530	2360	2300	0	0	0	0	84	82	84	85
11 Jun	133	2330	2460	2290	2210	0	0	0	0	82	82	84	83
25-Jun	146	2180	2340	2300	2100	0	0	0	0	78	80	79	72
9-Jul	7Lact	2060	2280	2390	1890	0	0	20	0	75	79	78	68
23-Jul	20	1990	2170	2410	1640	20	20	50	20	74	78	79	72
14 Aug	40	2140	2280	2560	1690	25	25	50	20	80	82	81	75
3-Sep	63	2230	2450	2620	1810	150	150	200	100	83	82	84	80

Round bales of hay were fed weekly in the plots with single bearing ewes and fortnightly in the plots grazed by twin bearing ewes. Ewes were supplementary fed lupins until approximately day 100 of pregnancy and then the lupins were replaced with commercially available pellets. The Table 8 below shows the nutritional quality of the components of the diet.

Table 8: Nutritional qualities of the components of the ewe’s diets

	Preferred pasture	Hay	Lupins	Pellets
Energy ME (MJ/kg)	4.4	9.5	13	10
Crude Protein (%)	5	6.4	36.9	12
Dry Matter (%)	87.8	84.7	92.3	88
Digestible DM (%)	35.1	64.6	94.1	
ADF (%)	46.6	30.3	19	Crude fibre 22%
NDF (%)	66.1	54	-	
WSC (%)	0.6	24.6	-	

Supplementary feeding rates in individual plots were adjusted according to the weekly weighing and condition scoring results. Generally the replicate plots received similar supplementary feeding with only slight adjustments (see appendix 1 for rates of supplement feed per plot). Figure 2 below shows the difference in total supplementary feed given per head to the different treatment groups during pregnancy and lactation. Lactation rations were started on day 148 of pregnancy. After the nutritional treatments ceased at around day 60 of lactation all ewes and lambs grazed as one mob on green pasture and were supplemented with hay.

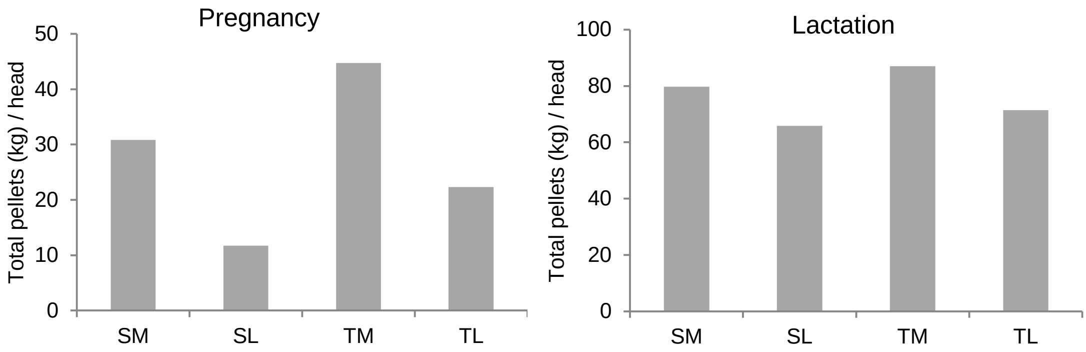


Figure 2: Total amount of pellets and lupins (kg) that ewes were supplemented with during pregnancy and lactation. Treatment groups were single-bearing ewes fed to maintain weight (SM) or lose weight (SL) and twin-bearing ewes fed to maintain weight (TM) or lose weight (TL).

Statistical analysis

All measurements were analysed by analysis of variance (ANOVA) testing the factorial combinations of nutrition treatment by pregnancy status with a block structure of block and plot within block (block/plot). There was no significant interaction (P>0.05) of nutrition treatment by pregnancy status for any of the analyses and so only the main effects of the nutrition treatments and pregnancy status will be presented. Progeny liveweight was predicted using restricted maximum likelihood (REML). Variables included were ewe liveweight at joining, ewe liveweight change at joining until Day 90 of pregnancy, ewe liveweight change from Day 90 of pregnancy until lambing, ewe liveweight change lambing to weaning. Where relivent, birth type or rearing type and sex of progeny were fitted as fixed effects and experimental blocking fitted as random effects. All possible models were examined to define statistical significance of effects of all terms and interactions thereof. Terms were retained if P<0.05.

4.3 Results

There was no significant interaction (P>0.05) of nutrition treatment by pregnancy status for any of the analyses and so only the main effects of the nutrition treatments and pregnancy status will be presented.

Ewe liveweights and condition score

Ewes in the lose treatment lost around 5kg of liveweight from day 90 until lambing and lost a small amount of condition (-0.2) (Table 9: Effect of nutritional treatments (Nt) and pregnancy status (PS) on condition score change and conceptus free liveweight change (kg) during pregnancy and lactation.Table 9). The change in liveweights of ewes ranged from +9 kg to -9 kg during pregnancy. The liveweight loss mainly occurred when ewes were fed around 4-5 MJ of metabolisable energy (ME) less than the maintenance ewes. However during lactation when they were only fed 2 MJ of

ME less than maintenance ewes there was no difference in condition score or liveweight change between the lose and maintenance treatments.

Table 9: Effect of nutritional treatments (Nt) and pregnancy status (PS) on condition score change and conceptus free liveweight change (kg) during pregnancy and lactation.

Measurement	**Nutrition (Nt)**		**Pregnancy status (PS)**		**L.S.D (P=0.05)**	**Significance[A]**
	Lose	***Maintain***	***Single***	***Twin***		
Condition score change						
Joining to lambing	-0.21	0.00	-0.09	-0.12	0.156	Nt: P<0.05 PS: n.s.
Lambing to end of experiment	-0.19	-0.18	-0.15	-0.22	0.083	Nt: n.s. PS: n.s.
Liveweight change						
Joining to lambing (kg)	-5.21	-0.20	-3.52	-1.89	0.702	Nt: P<0.001 PS: P<0.05
Lambing to end of experiment (kg)	1.40	-1.00	1.24	-0.84	3.777	Nt: n.s. PS: n.s.

[A] P value for F ratio, n.s. is P>0.05.

At the end of pregnancy there was a 5 kg difference between the lose treatment and the maintenance treatment and until day 44 of lactation there was a 2 kg difference between treatments. However, by the end of the experimental period the lose treatment had a similar weight to the maintenance treatment. There was a 0.15 difference in condition score at lambing and the difference in condition score between treatments was maintained until the end of the experiment at day 63 of lactation but by weaning at 86 there was no difference between treatments. Twin ewes were heavier than singles bearing ewes from the start of the experiment at day 90 and continued to be heavier during lactation (Table 10).

Table 10: Effect of nutritional treatments (Nt) and pregnancy status (PS) on condition score and conceptus free liveweight (kg) during pregnancy and lactation.

Measurement	Nutrition		Pregnancy status		L.S.D (P=0.05)	Significance[A]
	Lose	Maintain	Single	Twin		
Condition score						
Day 90 pregnancy	3.06	3.04	3.07	3.03	0.096	Nt: n.s. PS: n.s.
Day 146 pregnancy	2.79	2.94	2.86	2.88	0.106	Nt: P<0.05 PS: n.s.
Day 29 lactation- marking	2.55	2.75	2.72	2.57	0.143	Nt: P<0.05 PS: P<0.05
Day 63 lactation- end experiment	2.60	2.77	2.71	2.65	0.162	Nt: P<0.05 PS: n.s.
Day 86 lactation- wean	2.89	2.92	2.92	2.89	0.065	Nt: n.s. PS: n.s.
Liveweights (kg)						
Day 90 pregnancy	52.52	52.66	51.19	53.99	0.947	Nt: n.s. PS : P<0.01
Day 146 pregnancy	47.69	52.63	48.12	52.20	0.893	Nt: P<0.001 PS: P<0.001
Day 29 lactation- marking	53.94	55.52	52.02	57.44	1.170	Nt: P<0.05 PS: P<0.001
Day 44 lactation	50.13	52.39	49.41	53.11	1.784	Nt: P<0.05 PS: P<0.05
Day 63 lactation- end experiment	49.20	51.07	49.26	51.02	3.312	Nt: n.s. PS: n.s.
Day 86 lactation- wean	53.30	53.90	52.29	54.91	2.880	Nt: n.s. PS: n.s.

[A] P value for F ratio, n.s. is P>0.05.

The ewes were joined again 3 weeks after weaning the lambs. At joining there was no difference in weights or condition scores of the ewes from different nutritional treatments. The nutritional treatments did not affect fertility or conception rates of the ewes for the following joining (P>0.05). Ewes were able to gain weight after weaning and return to condition score 3 before joining.

Effects on the lambs

Lambs born to ewes that were fed to lose weight during late pregnancy were around 0.4 kg lighter at birth (P<0.05) (Table 11). Nutrition level of the ewe still had an influence over lamb weights at marking (3 weeks of age)(P<0.05). But by the end of the experiment at 6 weeks of age, nutrition of the ewe during pregnancy and lactation was not influencing lamb weight and it did not influence weaning weights or any other weights thereafter. Twin lambs were lighter than single born lambs at birth and at marking but by the end of the experiment at 6 weeks of age and thereafter there was no difference between weights of single and twin born lambs. The nutrition of the ewe during pregnancy did not influence lamb survival but twin born lambs had an 11% lower survival rate than single born lambs. Neither nutritional or pregnancy status of the ewe influenced weight change of the lambs from birth until weaning or weaning until 11 months of age.

Table 11: Effect of nutritional treatments (Nt) and pregnancy status (PS) on lamb weight, (kg) and lamb survival (%).

Measurement	Nutrition		Pregnancy status		L.S.D (P=0.05)	Significance[A]
	Lose	Maintain	Single	Twin		
Birth weight	3.88	4.28	4.43	3.73	0.156	Nt: P<0.05 PS: P<0.001
Weight at marking 3 weeks old	8.65	9.54	9.58	8.62	0.870	Nt: P<0.05 PS: P<0.05
Weight end of expt 6 weeks old	13.96	15.97	16.04	13.90	2.397	Nt: n.s. PS: n.s.
Weaning weight 12 weeks old	21.01	23.00	23.58	20.43	3.231	Nt: n.s. PS: n.s.
Lamb weight 11 months of age	36.17	37.82	37.77	36.23	2.865	Nt: n.s. PS: n.s.
Lamb survival 48 hrs (%)	91.44	91.95	97.48	85.91	5.344	Nt: n.s. PS: P<0.05
Weight change (birth - weaning)	17.13	18.72	19.15	16.70	3.138	Nt: n.s. PS: n.s.
Weight change (weaning – 11 mths)	15.16	14.82	14.19	15.79	2.005	Nt: n.s. PS: n.s.

[A] P value for F ratio, n.s. is P>0.05.

Lamb survival predictions

Predictions for lamb survival of different birth weights are shown in Figure 3. There were no interactions between survival and birth type (single or twin) or sex. Survival for 48 hours corresponds closely with survival until weaning. The ideal Dorper lamb birthweight seems to be around 4.5 kg for 96% survival and birthweights below 3.5 kg decrease the lamb's chance of survival until weaning to around 80%.

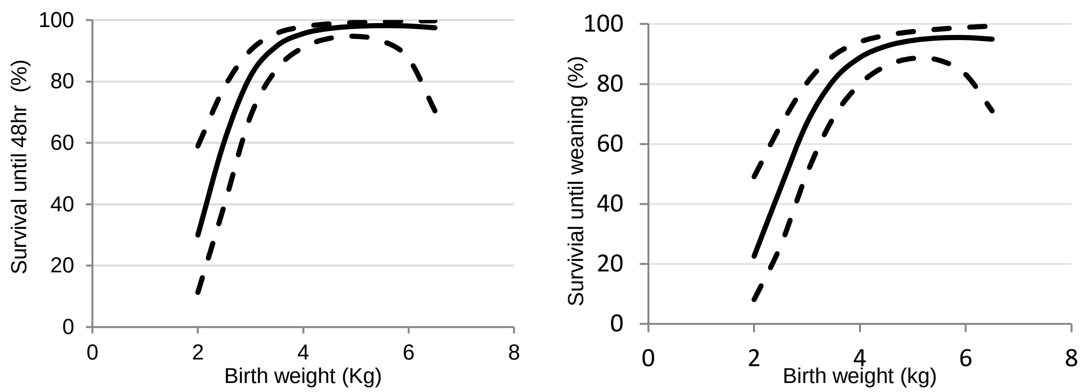


Figure 3: Predictions of the influence of birth weight on the survival of Dorper lambs from birth to 48 hours and from birth until weaning.

Predictions of lamb weights

Birthweight of the lamb can be predicted by ewe liveweight at joining, ewe liveweight change from joining to day 90 of pregnancy and day 90 to lambing as well as birth class (single or twin) and sex of the lamb. Ewes that are heavier at joining and gain more weight during pregnancy produce lambs with heavier birthweights. Male lambs are heavier than females and single-born lambs are heavier than twins (Table 12). An extra 10kg of ewe liveweight at joining gives an increase in 0.36 kg of birthweight. A loss of -10kg during early pregnancy (day 0 to 90) gives a decrease in birthweight by -0.35 kg. A -10kg loss in ewe liveweight in late pregnancy (90 to lambing) gives a decrease in birthweight of -0.22 kg.

Table 12: Coefficients (± s.e.) of REML linear models that predicts lamb birth weight (kgs) in terms of ewe liveweight (kg), birth class (single or twin) and progeny sex effects (fixed) after adjustment for blocking effects (random).

Coefficient	Birth Weight (kgs)
Constant[A]	2.50±0.384
Ewe liveweight at Joining	0.036±0.0073
Ewe liveweight change 0 to day 90	0.035±0.0139
Ewe liveweight change day 90 to lambing	0.022±0.0106
Birth class (twin)	-0.912±0.0817
Male	0.338±0.0759

[A] The birthweight constant is for birth class singleton born and a female progeny.

Weaning weights are also influenced by joining weight, liveweight change of ewes during pregnancy and also the liveweight change of ewes during lactation. Sex and rear type (twin raised as twin or singleton) has a large influence on weaning weight. A loss of 10 kg during either early or late pregnancy or decrease in 10kg of joining weight causes lambs to lose around 2.5kg of weaning weight. Ewe liveweight change during lactation (lambing to weaning) also has an impact on lamb weaning weight.

Table 13: Coefficients (±s.e.) of REML linear models that predicts lamb weaning weight (kgs) in terms of ewe liveweight (kg), rear type (twin or twin reared as single) and progeny sex effects (fixed) after adjustment for blocking effects (random).

Coefficient	**Weaning Weight (kgs)**
Constant[A]	12.09 ± 1.837
Ewe liveweight at Joining	0.231 ± 0.0353
Ewe liveweight change 0_90	0.248 ± 0.0654
Ewe liveweight change 90_lambing	0.273 ± 0.0567
Ewe liveweight change lambing to weaning	0.102 ± 0.0483
Ewe liveweight change lambing to weaning squared	-0.019 ± 0.0064
Twin reared as singleton	-2.17 ± 0.802
Twin reared as twin	-5.52 ± 0.423
Male	1.17 ± 0.347

[A] The weaner weight constant is for singleton born and a female progeny.

Ewe weight change during lactation influences weaning weight in a quadratic relationship. Weaning weight decreases with decreasing ewe liveweight change and begins to plateau as the ewe starts to gain weight (Figure 4).

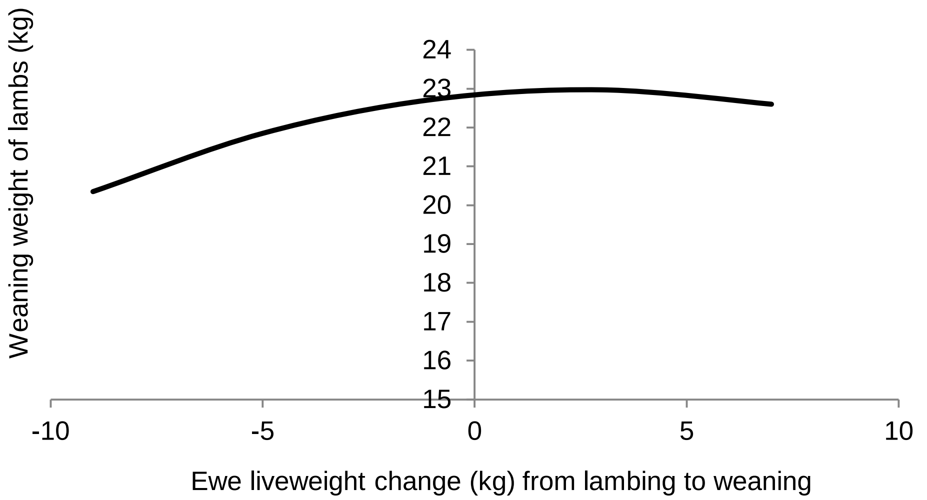


Figure 4: Relationship of ewe liveweight change during lactation (birth until weaning) on weaning weight of her lamb. The graph is for a 55kg ewe at joining and a mean effect of rear type and sex with no liveweight change of the ewe during pregnancy.

4.4 Discussion

Birthweight and weaning weight of Dorper lambs is influenced by ewe liveweight at joining and ewe liveweight change during pregnancy and lactation which supports our hypothesis. Our results are similar to those seen in Merino ewes (Oldham et al., 2011; Thompson et al., 2011), Merino cross Border Leicester ewes (BLM) and Merino ewes mated to terminal sires (TM) (Paganoni et al., 2014). Birthweight of Dorper lambs is influenced by the same factors as Merinos with a slightly lower co-efficient for ewe liveweight change in late pregnancy (co-efficient of 0.045 for Merinos vs 0.022 for Dorpers) whereas joining weight seems to have slightly larger effect in Dorper ewes than Merinos (0.027 for Merinos, 0.036 for Dorpers). Similar co-efficients for birthweights have also been reported for BLM ewes and TM lambs (Paganoni et al., 2014). Influence of ewe liveweight profile during pregnancy on weaning weights are also similar between Dorpers and Merinos with similar co-efficients (Thompson et al., 2011). Ewe weight change in late pregnancy seems to be slightly more influential on lamb birthweights in Dorpers than Merinos and BLM and TM lambs (0.27 for Dorpers, 0.1 for Merinos and 0.086 for BLM and TM) (Paganoni et al., 2014; Thompson et al., 2011). Other studies have showed similar responses in lamb birthweight to ewe nutrition during pregnancy (see Greenwood (2010) for review). Our results show that the liveweight profile of the ewe during pregnancy influences birthweights and weaning weights in Dorper lambs similar to that seen in Merinos.

Ewe liveweight change during lactation also significantly influences weaning weights and our study showed a quadratic effect. Growth rate of lambs increases with increased milk production and energy intake of the ewe (Mikolayunas et al., 2008; Morgan et al., 2007). The quadratic relationship we found in Dorpers shows that during energy deficit, ewes mobilise body reserves and decrease milk production which is why ewes that lost the most weight during lactation had the lightest lambs at weaning. This relationship starts to plateau when ewes are maintaining weight because they are at their peak milk production so weaning weight shows no further increase and surplus energy can be partitioned towards weight gain of the ewe. The way that the ewe partitions her energy intake between milk production and liveweight change determines the relationship between ewe liveweight change and lamb growth rate and this can differ between breeds (Morgan et al., 2006). In Merinos there is no relationship of lamb growth rate to ewe liveweight change but a strong quadratic relationship with food on offer (Thompson et al., 2011). If we had a range of supplementation rates in this study we would likely have seen a similar strong effect, much more so than ewe liveweight change as energy intake directly relates to milk production (Jordan and Mayer, 1989; Mikolayunas et al., 2008). In dairy ewes there was a positive linear relationship between ewe weight change during lactation and milk production of the ewe, but the weight change range was limited between – 2.4kg and +0.5kg (Mikolayunas et al., 2008). Whereas there is a negative linear relationship between milk yield and ewe liveweight in some temperate breeds but there was no variation in feeding level in this study (Morgan et al., 2006). Breeds of sheep differ in nutrient partitioning during lactation which is why there are a range of responses of weaning weight to ewe weight change during lactation. Our study shows that for Dorpers, ewes should be fed to maintain weight to achieve the highest weaning weights of lambs.

The optimum birthweight of Dorpers seems to be around 5 kg to maximise lamb survival. The optimum range of birthweight seems to be between 4-6kg for around 90% and above chance of survival. Lambs below 3.5 kg which occurs in twins are at a high risk of mortality. The optimum birthweight of Dorpers are similar to those for Merinos (Atkins, 1980; Fogarty et al., 1992; Oldham et al., 2011). However, unlike Merinos, birth type (single or twin) and sex in Dorper lambs does not seem influence their survival other than their effect on birthweight (Oldham et al., 2011). The reason for this difference from Merinos is unclear but it could be due to breed differences in both ewe and lamb behaviour which influences lamb survival (Dwyer, 2003). Producers can use the relationships found in this study to predict birthweight and subsequent lamb survival rates.

Previous reports of high lamb mortality rates in Dorpers when fed the same as Merinos may have been due to too higher birthweights. When Dorper and Damara sheep were run with Merinos and managed according to the optimal liveweight profile of the Merino ewe, reproductive rates of Dorper and Damara sheep were low (Kilminster and Greeff, 2011). In this study, mature Dorper ewes had high rates of conception over the two years of the trial (155% year 1, 159% year 2) and high lambing percentage (145% and 132%). However there were very high rates of lamb mortality between birth and weaning in both years (23% and 27% mortality). The authors suggested that under the annual mating system and optimal feeding conditions for the Merino, Dorper ewes became over-fat and this lead to a high mortality rate in lambs possibly due to dystocia. Birthweights were not measured in the above study however, using the predictions of our experiment we can estimate that with the joining weights of 77kg stated in the study and small weight gain over pregnancy it is likely that lambs were above the optimum weight range which may have led to a higher mortality as it does in Merinos (Oldham et al., 2011). Therefore, overfeeding Dorpers can pose a threat to lamb mortality and producers need to ensure that ewes are fed appropriately so that lamb birthweights are in the optimum range for high lamb survival.

The only other nutritional study on Dorper reproduction in Australia concluded that Dorpers should not be managed under a nutritional system that is optimum for the Merino, but our results indicate the contrary (Kilminster and Greeff, 2011). Dorpers in the Kilminster and Greeff study (2011) were run with Merinos and feeding decisions were based on the condition and liveweight change of Merinos. Although Dorpers were consuming the same forage and supplements as Merinos, they gained more weight and were a higher condition score than Merinos which resulted in Merinos being optimum weights and Dorper ewes becoming over-fat. There is evidence that arid-type breeds differ from temperate wool breeds in their food intake and digestibility of dry matter and possibly energy requirements (Deng et al., 2014; Silva et al., 2004; Wilkes et al., 2012) which may explain these differences in weight gain, however specific differences between Dorpers and Merinos have not been examined. The collective data of the Kilminster and Greeff trial (2011) and the current study show that Dorpers should be managed to similar liveweight profiles as Merinos but managed separately as a mob so their specific liveweight targets can be met and breed differences in liveweight gain avoided.

Since the relationship of ewe liveweight profile to birthweight and weaning weight are similar between Dorpers and Merinos, we may be able to use the previous research conducted on whole farm profitability of Merinos and apply to Dorper flocks. Young et.al., (2011) found that the optimal liveweight profile for highest whole farm profit of the Merino enterprise in southern Australia is to join ewes at 90% of the standard reference weight for the genotype, ewes can lose a small amount of weight (around 3 kg) after joining but this weight needs to be regained by lambing to ensure optimum lamb birthweights. This system was similar for all three climatic regions studied; south-west Victoria, Great Southern Western Australia and southern New South Wales. Optimum liveweight profiles were insensitive to changing commodity prices, pasture productivity and management. This system also took into account the impact of ewe nutrition on wool production of the ewe and lamb (fibre diameter and clean fleece weight). This is not relevant to hair sheep such as the Dorper, but any gains in wool production should translate to liveweight gains since the two are linked (Ferguson et al., 2011). Liveweight gains in Dorpers would also represent an increased profit through higher reproduction rates of the ewe and liveweight of the lamb. Therefore, these profiles could also be applied to Dorper ewes in those specific regions.

A possible limitation to the Merino system is that it is based on annual spring lambing which may not be the case for Dorpers. Whole-farm profit and optimal maternal liveweights were done on spring-lambing annual mating (Young et al., 2011) whereas in Dorpers, in an accelerated mating system (every 8 months) ewes will only be lambing in spring some of the time. In more seasonal regions such as the Great Southern in Western Australia, cost of supplementary feeding lactating ewes when there is little pasture available (in summer or Autumn lambing) will be very high. This high cost of feeding may outweigh the added gains in lamb survival and weaning weight making it more economical to feed ewes below maintenance for a short period of time. Ideally, the data from this experiment could be used in the models presented by Young et al. (2011) to determine whole farm profit for Dorpers lambing at different times of the year and determine optimal liveweight profiles for farmers. However, this is beyond the scope of the current study. To help determine whether it is more economical to feed sheep to maintenance or allow ewes to lose weight, we have developed a trial spreadhseet that could be available on the Facey Group website (see Factsheets, Appendix 2). When lambing out of season, farmers can use the data from this experiment as a basis to determine the optimal ewe liveweight profile based on the feed resources available, cost of supplementary feeding and current lamb prices.

In order to apply the Merino optimal maternal liveweight to Dorpers for spring lambing, we need to determine their standard reference weight. There does not seem be a standard reference weight for a Dorper ewe however it is likely to be higher than a Merino. Joining weights were around 52 kg in this study however results from experiment 1 show that higher joining weights increase conception. Joining weights would also be heavily influenced by mating frequency and management conditions. Table 14 shows joining weights of ewes in the available references for Dorpers and the management conditions they were under in the various studies.

Table 14: Reported joining weights of mature Dorper ewes, the mating frequency, management and location.

Joining body weight	Mating frequency	Management system	Reference
52 kg	8 months	Mediterranean climate, pasture with supplements. Western Australia	This study
73 kg (avg 2 yrs)	Annual	Pasture with supplements, Western Australia	(Kilminster and Greeff, 2011)
61 kg	8 months	Pasture, supplemented when ewes were in condition score 2-2.5. South Africa	(Schoeman and Burger, 1992)
72 kg	Annual	Semi-arid, minimal pasture improvements. South Africa	(Cloete and De Villers, 1987)
57 kg	Annual	Semi-arid, no supplements. South Africa	(Snyman and Olivier, 2002)
74 kg	8 months	Pellets 10.5 MJ ME/kg, 0.6kg per day. South Africa	(Schoeman et al., 1993)
Average of all references: 65 kg joining weight			

As Table 14 shows, there is a large variation in joining weight, even within similar management systems. Within-breed differences in liveweight may also exist in different genotypes, but there is not enough information on the breed to judge this. With the information available (Table 14), we estimate that standard reference weight for the Dorper should be 65 kg but farmers are encouraged to determine the reference weight for their individual flock. Following the Merino recommendations, 90% of the standard reference weight of Dorpers at 65kg is 58.5kg which ewes should be joined at. However we recommend a slightly higher joining weight of 60kg for Dorper ewes for two reasons. First, the large response of conception and fertility to higher joining weights in Dorpers means that more lambs will be conceived. Second, at a joining weight of 60kg and no ewe liveweight change during pregnancy, the birthweight of twin born lambs will be 4kg and above which is optimum for survival. Therefore, data from the two experiments in this study show that Dorper ewes should be 60kg or more at joining for optimum reproductive rates.

The condition score of Dorper ewes seems to be less sensitive to changes in liveweight than Merino ewes. In this experiment, ewes lost -5kg of liveweight and this only corresponded to a 0.2 decrease in condition score. In Merinos a 5kg of weight loss corresponds to around 0.5 condition score (van Burgel, 2011). Data from van Burgel et.al., (2011) shows that in Merinos, one condition score is equivalent to 0.19 times the standard reference weight of the ewe. At a standard reference weight for Dorpers at 65 kg, a loss of 5 kg would mean a condition score loss of 0.4 rather than the observed 0.2. Although condition score is a subjective measurement, it was noted that Dorper ewes lost condition from their backbone and hindquarters yet there remained substantial coverage on their short ribs. Breed differences in where muscle and fat are utilised in the body may account for the discrepancy in condition score values to weight loss. Since condition score changes seem to less sensitive to liveweight changes in Dorpers than Merinos, it is recommended that Dorper producers use liveweight guidelines for decision making tools rather than condition score.

5. Overall recommendations from both experiments

For the highest reproductive rates in Dorpers, producers should manage their ewes to the following guidelines:

Joining:

- Ewes should be joined at 60kg and above
- Be gaining liveweight and on an increasing plane of nutrition in the two weeks pre-joining and first week of joining
- Be fed 200g/h/d of lupins two weeks before and the first week of joining

Pregnancy and lactation nutrition:

- Producers should aim for optimum birthweight of lambs at around 4-6kg.
- For optimum birthweight and highest weaning weights, ewes that are 60kg at joining should be managed to maintain liveweight during pregnancy and lactation. However, this may not be economical depending on farming region and season of lambing.
- For ewes lambing in spring, producers can follow the lifetime ewe management guidelines for Merinos for their region (www.lifetimewool.com.au).
- For ewes lambing at other times of the year when feed costs are higher such as autumn, producers can use the coefficients found in this experiment (Table 12 and 13) to assess the impact of ewe liveweight and liveweight change on the lamb. To help make feeding decisions, farmers can download a spread sheet from the Facey Group website (www.faceygroup.org.au). This helps farmers to compare the cost of feeding the ewe verses the benefit in lamb weights to ascertain the most cost effective feeding strategy.

- Producers should use ewe liveweight change rather than condition score change to access the progress of the Dorper ewe as condition score is less sensitive to changes in liveweight than Merinos.

6. Communications and extension

Below is a list of all media articles, field walks, presentations and report publications that have been extended to farmers from April 2013 to March 2015. Copies of all of the below documents and presentations are available in pdf form on request.

- Ripe (FairFax Media) - April 2013 Volume 7 Number 4: **Birds of a feather…**(pg. 4 & 5)
- Media Release - 8th April 2013: **MLA invests in local group to improve Dorper knowledge**
- **Sheep Health and Handling Update** - 3rd July 2013: Field Walk and Update of Facey Group Dorper nutrition Trial: Presented by Dr Megan Gooding
- **Wickepin Regional Sheep Updates** - 24th July 2013: **Facey Group Dorper research: nutritional management of Dorpers for reproduction and growth**: Presented by Dr Megan Gooding.
- Facey Group Spring Field Day Publication - September 2013: **Optimising reproduction in the Dorper ewe through nutrition - Experiment 1.** (pg. 30) & **Experiment 2** (pg. 32).
- Media Release - September 2013: **Dorpers are different - optimising reproduction in the Dorper ewe through nutrition**
- Feedback: Your Levies at Work Publication - October 2013: **Planning for reproductive gains** (pg. 12 & 13).
- Facey Group Trials Presentation Event Publication - March 2014: **Optimising reproduction in the Dorper ewe through nutrition - Experiment 1.** (pg. 57) & **Experiment 2** (pg. 60).
- Ovine Observer - July 2014 Issue #67 ISSN 1835-8675: **Optimising reproduction in the Dorper ewe through nutrition** (pg.4-6)**.**
- Facey Group Trials Presentation Event - 5th March 2015: **Feeding the Dorper ewe reproduction line.** Presented by Dr Megan Gooding.
- Facey Group Trials Presentation Event Publication - March 2015: **Feeding the Dorper ewe reproduction line - Experiment 1.** (pg. 67) & **Experiment 2** (pg. 71).

Experiment 2 has been submitted as a paper to a special Sheep Reduction edition of the journal Animal Production Science. Experiment 1 is pending submission into a journal.

Once the final report is approved by MLA, the report and other extension tools such as the cost/benefit spread sheet will be available for download on the Facey Group website. In addition to this the factsheets in Appendix 2 will be available on the website and be available to farmers at every sheep-related event the Facey Group runs for the next 12 months. These fact sheets can also be used by MLA for future media releases.

Appendix 1

Table 2: Quantity of supplementary feed given to ewes (grams/head/day) of different treatments and replicates (plots). Day of gestation indicates the gestational stage at which the feeding regime started.

Day of gest	Supp type	Single bearing (g/h/d)				Supp type	Twin bearing (g/h/d)			
		Maint	Maint	Lose	Lose		Maint	Maint	Lose	Lose
		Rep1	Rep 2	Rep1	Rep 2		Rep1	Rep 2	Rep1	Rep 2
90	Lupins	250	250	100	100	Lupins	330	330	170	170
104	Lupins	100	100	0	0	Lupins	430	430	200	200
107	Lupins	200	200	50	50	Pellets	300	300	200	200
112	Lupins	200	200	50	50	Pellets	300	300	200	200
119	Pellets	400	400	0	0	Pellets	700	700	300	300
126	Pellets	600	600	150	100	Pellets	1000	1000	500	500
134	Pellets	900	800	250	200	Pellets	1100	1200	500	550
140	Pellets	900	800	500	550	Pellets	1100	1100	600	500
1 lact	Pellets	1100	1100	900	900	Pellets	1200	1300	1000	1000
21	Pellets	1500	1500	1300	1300	Pellets	1600	1600	1400	1400
27	Pellets	1300	1300	1200	1100	Pellets	1400	1400	1200	1200
41	Pellets	1400	1400	1100	1100	Pellets	1500	1500	1200	1200
61	Treatments end									

Appendix 2

Feeding the Dorper ewe reproduction line

Facey Group Inc and Meat and Livestock Australia
Kelly Pearce and Megan Gooding
Contact: Sarah Hyde, eo@faceygroup.org.au

Introduction
Dorper ewes have the capacity to produce quality lambs year-round to supply both international and domestic sheepmeat markets. The two phases of reproduction that are the most critical to increasing reproductive rates are joining for maximum conception of lambs, and late pregnancy and lactation for maximum survival and growth rates of lambs. Nutrition of the ewe during joining, pregnancy and lactation determines her reproductive success and the birthweight and weaning weight of her lamb which ultimately influences whole farm profit. Here are a few general guidelines to follow for feeding Dorper ewes during reproduction.

Nutrition at joining
There are three main factors that influence both fertility of Dorper ewes (ewes pregnant per ewes mated) and conception rate (lambs scanned per ewes mated). These are liveweight, liveweight gain and nutrition. To increase both fertility and conception follow the below guidelines at joining:

- High ewe liveweight at joining (60kg or more) and ewes should be in condition score 3 and above.
- Ewes should be gaining weight pre and early joining
- Feed 200g/h/d of lupins for 3 weeks for the 2 weeks before joining and the first week of joining.

The 200g/h/d lupin supplement should be fed above providing enough feed for the ewes to maintain weight. This supplement should be fed when joining over summer, autumn and early winter. When more pasture is available during late winter and spring it may not be necessary. Table 1 below shows predictions of fertility and conception rate of ewes for different liveweight and liveweight change in the two weeks before and during the first week of joining. Predictions are based on a summer joining when grazing wheat stubble or grazing the same wheat stubble with a 200g/h/d lupin supplement for the two weeks prior to and first week of joining.

For example, for ewes who are 60 kg and have gained an average of 2kg of liveweight in the 2 weeks prior to and first week of joining, we would expect the mob to have a fertility of 93% and conception rate of 112% when grazing wheat stubble. But, if we give them an additional 200g/h/d of lupin supplement their fertility would be 97% and conception rate would be 133%. As this table shows, combining all three influencing factors of high liveweight, increasing plane of nutrition and a 200g/h/d lupin supplement in the two weeks prior to and first week of joining gives the highest conception rate prediction.

Table 1: Predictions of fertility (ewes pregnant/ewes mated %) and conception rate (lambs scanned/ewe mated %) for different ewe joining weights and liveweight change of ewes in the two weeks before and first week of joining. Predictions are based on ewes grazing a wheat stubble in summer with no supplements or in addition to this, receiving 200g/h/d of lupin supplement in the two weeks before and first week of joining.

Ewe Liveweight (kg)	*Ewe Liveweight change (kg)*	*No lupin supplement*		*Lupins 200g/h/d for 3 weeks*	
		Fertility %	*Conception %*	*Fertility %*	*Conception %*
60	5	95	120	98	141
	2	93	112	97	133
	0	91	107	95	128
	-2	88	102	94	123
	-5	83	94	92	115
55	5	93	111	96	132
	2	89	104	95	124
	0	87	98	93	119
	-2	83	93	91	114
	-5	76	85	88	106
50	5	89	103	95	123
	2	85	95	92	115
	0	81	89	90	110
	-2	76	84	87	105
	-5	68	76	82	97
45	5	84	94	92	115
	2	78	86	87	107
	0	73	81	86	101
	-2	68	75	82	96
	-5	58	67	75	88

In management systems where Dorper ewes are mated every 4-9 months, there is little time between weaning lambs and the next joining. Therefore, ewes should be in good condition at the end of lactation to ensure adequate liveweights for the next joining.

Dorper ewes should not be fed 500g/h/d of lupins or more when grazing as it causes them to lose weight.

The condition score of Dorper ewes is less sensitive to changes in liveweight as Merino ewes. Therefore, where possible, liveweight change rather than condition score change should be the basis for management decisions.

Nutrition during pregnancy

Ewes should be pregnancy scanned around day 80, dry ewes removed and twin bearing ewes identified. Twin bearing ewes should be managed separately from single bearing ewes so that they can be given the higher plane of nutrition that they require.

The most important factor in high reproductive rates after conception is the survival of lambs after they are born. The single largest contributor to lamb survival is the birthweight of the lambs. Therefore it is imperative that lambs be born at weights optimal for lamb survival. Figure 1 shows the optimum lamb birthweight for Dorpers to ensure the highest survival rate until weaning.

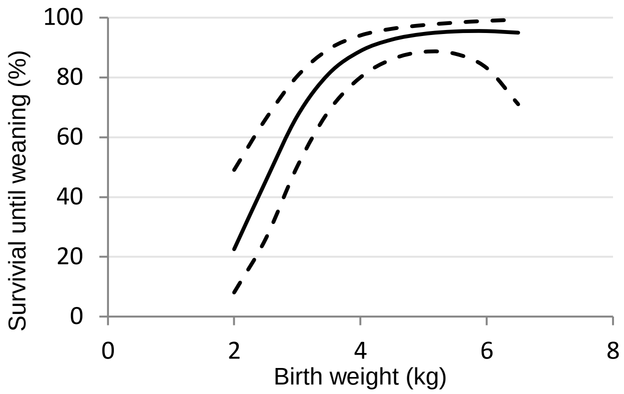


Figure 1: Influence of birth weight on the survival of Dorper lambs from birth until weaning.

For the highest survival rates, Dorper lambs should be 4-6kg at birth. When birthweights are below 3.5, survival rates drop to below 80%. Twins are at particular risk as their birthweights are around 1 kg lighter than single born lambs.

Birthweight of lambs can be managed through the nutrition of the ewe during pregnancy. The main drivers for birth weight and weaning weight in Dorper lambs are:
- Ewe liveweight at joining
- Ewe liveweight change during pregnancy
- single or twin born lamb
- sex of the lamb

Ewes that are heavier at joining and gain more weight during pregnancy produce lambs with heavier birthweights and weaning weights. Single born lambs and male lambs are also heavier at birth and weaning. Ewe weight change during early and mid pregnancy (joining to day 90) has a similar effect on birthweight as ewe weight change in late pregnancy (day 90 to lambing). The graphs below illustrate these relationships for single-born male lambs (Figure 2) and twin born male lambs (Figure 3).

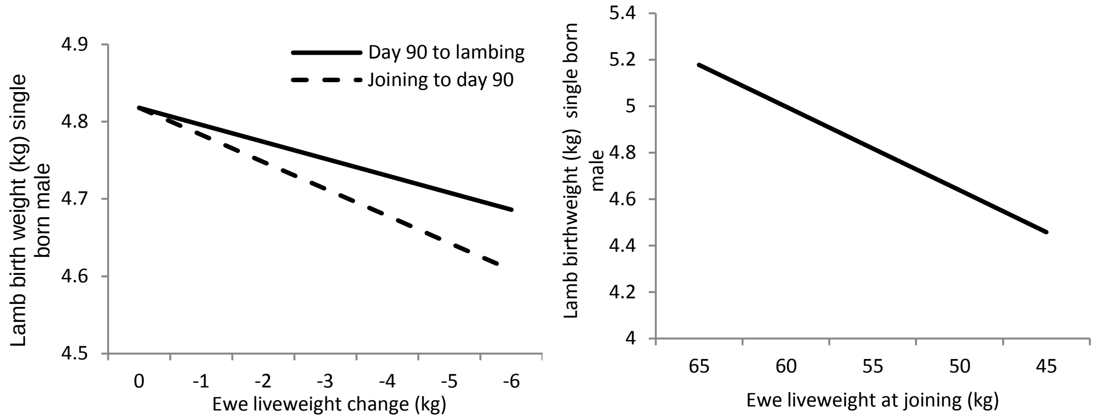


Figure 2: Predictions of birthweight of a SINGLE born male Dorper lamb born to a 55kg ewe at joining for changes in ewe liveweight from joining to day 90 and day 90 to lambing. The influence of ewe liveweight at joining on birth weight is also shown for a ewe that maintains weight during pregnancy.

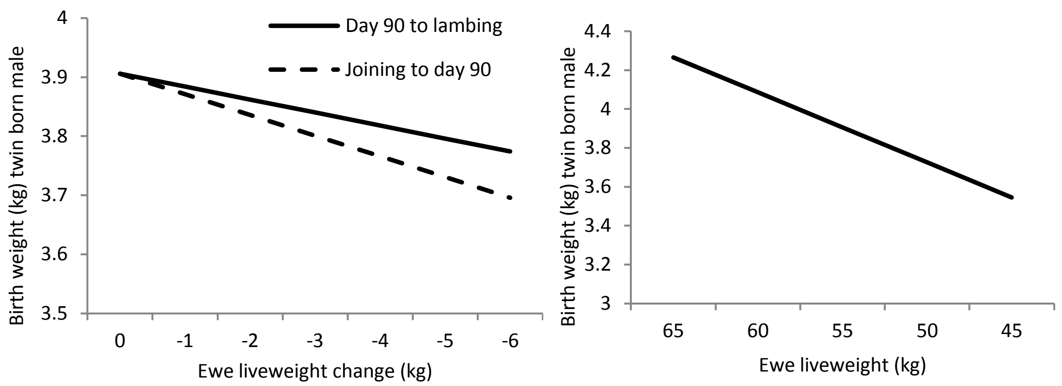


Figure 3: Predictions of birthweight of a TWIN born male Dorper lamb born to a 55 kg ewe at joining for changes in ewe liveweight from joining to day 90 and day 90 to lambing. The influence of ewe liveweight at joining on birth weight is also shown for a ewe that maintains weight during pregnancy.

Birth weight of single born male lambs does not go below 4 kg with changes in ewe liveweight of -5kg or joining weights 45kg or above (Figure 2). This means that survival is less likely to be effected by these parameters within that range as shown by the survival prediction in Figure 1. However, for twin born lambs who are around 1kg lighter than single born lambs at birth, when the ewe loses weight during pregnancy or has a lighter weight at joining, birthweight will go below 4kg so survival rate of the lamb is likely to decrease. Therefore, to maximise survival of twin lambs, twin bearing ewes should be fed to maintain liveweight during pregnancy. When nutrition is limiting this may mean separating them from single bearing ewes whose liveweight can decrease slightly during pregnancy without influencing survival greatly.

Weaning weight of lambs is influenced by the same factors as birthweight. So, if ewes are lighter at joining and/or lose weight during pregnancy they will wean lighter lambs. Weaning weight of lambs is decreased by approximately 1 kg for a 5 kg loss in ewe liveweight during pregnancy or if the ewe is 5 kg lighter at joining (Figure 3).

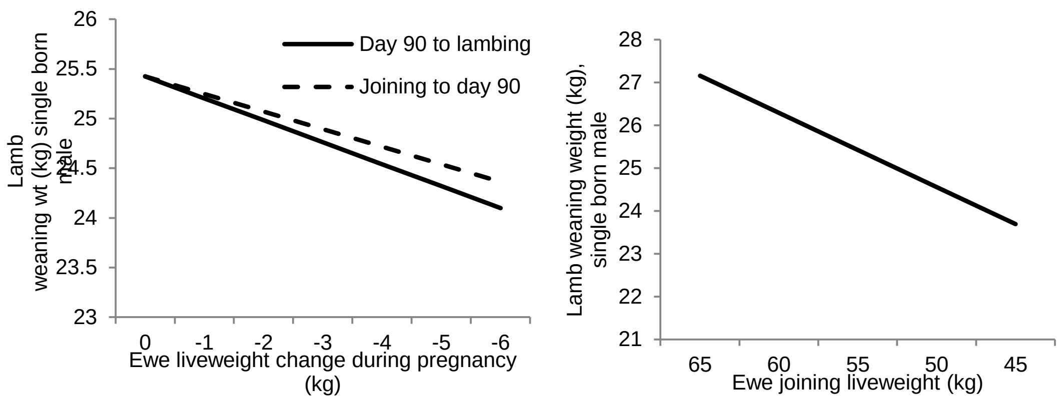


Figure 4: Predictions of weaning weight of a SINGLE born male Dorper lamb born to a 55 kg ewe at joining for changes in ewe liveweight from joining to day 90 and day 90 to lambing. The influence of ewe liveweight at joining on birth weight is also shown for a ewe that maintains weight during pregnancy.

As previously mentioned, condition score of Dorper ewes is less sensitive to changes in liveweight than Merino ewes therefore liveweight change should be used rather than condition score to ascertain the effects of nutrition. The liveweight of the ewe will increase during pregnancy as the fetus grows so this should be taken into account by measuring conceptus-free weight (liveweight minus foetus and placenta). The conceptus will account for around 2kg in a single bearing ewe and 3kg in a twin bearing ewe at day 100 of pregnancy and by lambing around 6kg for single-bearing ewes and 9kg for twin bearing ewes. For more information, download the spread sheet from the Facey Group website (see more information section).

Nutrition during lactation

The main influence of the weaning weights of lambs is the amount of feed available to the ewe during lactation. As ewes are producing milk for their lambs, this is the time when they have their highest nutrient requirements, especially twins. For high weaning weights, it is important that ewes are fed to meet their energy requirements during lactation. In Dorper ewes, weaning weight decreases as ewes lose weight during lactation (Figure 5). Weaning weight starts to plateau as ewes gain weight as this is when milk production will be at its highest level for lamb growth.

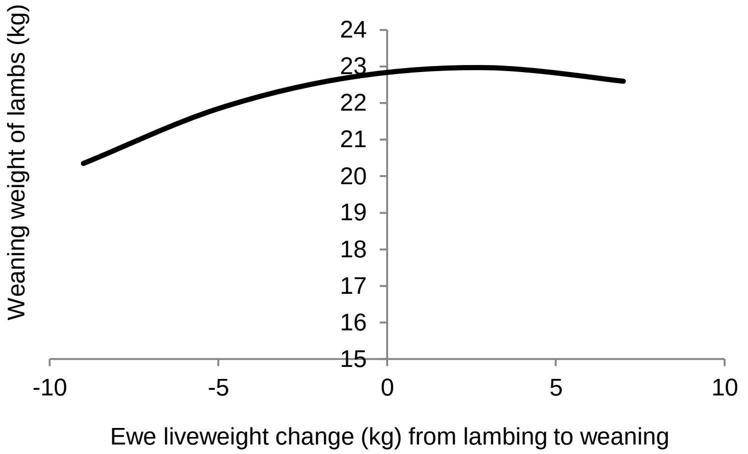


Figure 5: Relationship of ewe liveweight change during lactation (birth until weaning) on weaning weight of her lamb. The graph is for a 55kg ewe at joining and a mean effect of rear type and sex with no liveweight change of the ewe during pregnancy.

This shows that for the heaviest lambs at weaning, Dorper ewes should be fed to maintain weight during lactation. Refer to the last section for references on where to find more information on energy requirements for ewes during lactation.

When Dorper ewes are being mated every 8 months or less there is only a short period of time between weaning lambs and the next joining. For this production system, producers need to ensure that ewes are at high liveweight for joining so this may mean that ewes need to be fed more during late lactation to increase liveweight to optimum levels.

Cost effective feeding

Overall, the best reproductive rates of ewes and high lamb weights will be achieved when ewes have high liveweight and maintain weight over pregnancy and lactation, but this is not always economical. Dorpers are similar to Merinos in the response of birthweight and weaning weight to ewe nutrition. Therefore, recommendations for the most cost-effective feeding regimes for Merinos will also apply to Dorpers (see further information on last page). However, these recommendations are only ewes that are lambing in spring. When lambing at other times of the year, producers must do their own calculations on what feeding level is most cost-effective for their individual farm and feed resources available to them.

Producers can use equations on the influence of ewe liveweight change on birthweight and weaning weight to help develop the most cost-effective feeding strategy for their farm. If ewes are lambing during autumn for example when pasture quality and quantity is low, the cost of supplementary feeding the ewe to maintain weight might be more than the benefit of increased lamb survival and weaning weight of the lamb that this achieves. Therefore, feeding ewes below maintenance may be more economical at this time of year. Estimated liveweight loss of the ewe on different feeding regimes can be put into an equation so that birthweights and weaning weights can be predicted and production losses calculated. A spread sheet of these equations can be downloaded from the Facey Group website to assist producers in making these decisions (see more information section below). This will allow farmers to develop cost-effective feeding regimes to maximise reproductive rates for lambing at any time of the year on their individual farm.

More information
All Dorper trial data as well as calculation spread sheets on cost-benefit of feeding ewes and conceptus-free liveweight calculation. Also a review of the literature on nutrition of Dorper sheep can be downloaded from the Facey Group website: www.faceygroup.org.au. Located in the Projects section.

Information on the optimal nutrition for spring lambing in different regions of Australia can be found from the lifetime wool website. This website also includes information on feed budgeting for different times of the year and well as pasture evaluation: www.lifetimewool.com.au

The Meat and Livestock Australia website provides many different tools to assist farmers in making production and business decisions including a feed demand calculator and stocking rate calculator: http://www.mla.com.au/News-and-resources/Tools-and-calculators

Other useful tools can be found at the "making more from sheep" website:
http://www.makingmorefromsheep.com.au/index.htm
Grazing information is available at Evergraze: http://www.evergraze.com.au

Appendix 3: Calculations sheets to determine cost benefits of ewe feeding for different changes in liveweight

Cost benefit analysis of supplementary feeding Dorper ewes during pregnancy and lactation

Green highlights for farmers to fill in

Feeding ewes	Example values	INSERT Your Values
Cost of supplementary feed ($/t) (e.g. Oats)	280	280
Metabolisable Energy value of feed (ME, MJ/kg Dry matter), see table on next sheet	10.4	10.4
Dry matter of feed (%)	90	90
Metabolisable Energy of Feed on "as fed" basis	9.5	9.5
Percentage of twin-bearing ewes in mob	30	30
Feeding the Lambs to slaughter weight		
Cost of finishing diet (e.g. pellets) ($/t)	350	350
Price of lambs ($/kg carcus weight)	5.5	5.5
Desired slaughter weight	46	46
Growth rate (g/h/d)	150	150
Consumption of pellets (g/h/d)	800	800
Potential total profit on lamb when taken to slaughter weight ($/h)	40	40

Ewe liveweight change

1. Enter in ewe liveweight at joining, must be the same for Senario 1 & 2
2. Leave Senario 1 as ewes maintaining liveweight
3. Change Senario 2 to desired weight LOSS e.g. -3 for 3kg weight loss (not be be applied for weight gain)

	Senario 1 Ewes Maintain weight	**Senario 2 Ewes lose wt**
Ewe liveweight at Joining	60	60
Ewe liveweight change Joining to day 90	0	0
Ewe liveweight change day 90 to lambing	0	-5
Ewe liveweight change lambing to weaning (0-80 days lamb age)	0	0
Liveweight of ewe at weaning- 2 weeks before next joining	60	55
Expected ewe liveweight change in 2 weeks before and first week of joining (kg) (e.g range of -5 to +5 kg) (based on weight change 2 weeks pre and first week of joining)	0	0

Cost/Benefit

Does cost saving of feed outweigh the loss in profit of having lighter lambs at weaning and lower survival?
If below numbers are positive then it does and it is more profitable to feed ewes below maintenance
If negitive then it is more profitable to feed sheep to maintenance levels

Cost/benefit ($/h) for combined single and twin mob	-1.27
Cost/benfit ($/h) for single-bearing ewe mob	-1.11
Cost/benefit ($/h) for single-bearing ewe mob	-1.66

To calculate conceptus-free liveweight of ewe (liveweight minus feotus and placenta):

1. Enter day of pregnancy in first green box counting from when rams were put in with ewes
2. Enter current liveweight of ewe in second green box.

Day of pregnancy		146
Birthweight of Single-born lamb		4.5
Birthweight of twin-born lamb x 2		7.0
	Single	Twin
Kg weight of conceptus (kg)	0.0	0.0
Liveweight of ewe (kg)	63.0	
Conceptus-free liveweight of ewe single-bearing		*63.0*
Conceptus-free liveweight of ewe twin-bearing		*63.0*

7. References

Atkins, K. 1980. The comparative productivity of five ewe breeds. 1. Lamb growth and survival. Australian Journal of Experimental Agriculture 20: 272-279.

Basson, W. D., B. D. H. Van Niekerk, A. M. Mulder, and J. G. Cloete. 1969. The productive and reproductive potential of three sheep breeds mated at 8 monthly intervals under intensive feeding conditions. Proceedings South African Society of Animal Production 8: 149-154.

Brand, T. S., and F. Franck. 2000. Production responces of two genetic different types of Merino sheep subjected to different nutritional levels. Small Ruminant Research 37: 85-91.

Campbell, A. J. D., Vizard., A.L., Larsen., JWA. . 2009. Risk factors for post-weaning mortality of Merino sheep in south-eastern Australia. Australian Veterinary Journal 87: 305-312.

Chadwick, M., and K. Pearce. 2012. Nutritional management of dorpers of reporduction and growth in Australia: A literature review. Meat and Livestock Australia Limited. Sydney, NSW, Australia. .

Cloete, S. W. P., and T. T. De Villers. 1987. Production parameters for a commercial Dorper flock on extensive pastures. South African Journal of Animal Science 17: 121-127.

Croker, K., M. Johns, and T. Johnson. 1985. Reproductive performance of Merino ewes supplemented with sweet lupin seed in southern Western Australia. Australian Journal of Experimental Agriculture 25: 21-26.

DAFWA. 2008. Lambing planner. Virtual Shepherd Department of Agriculture and Food Western Australia Version 3.

De Waal, H. O., and L. C. Biel. 1989. Supplementation of lactating Dorper and Merino ewes on Themeda-Cymbopogon veld 1. Body mass changes of ewes and their lambs. South African Journal of Animal Science 19: 141-147.

Degen, A. A., and M. Kam. 1991. Energy intake, nitrogen balance and water influx of Dorper sheep when consuming different diets. Journal of Arid Environments 21: 363-369.

Deng, K. D. et al. 2014. Energy requirements of Dorper crossbred ewe lambs1. Journal of Animal Science 92: 2161-2169.

Dwyer, C. M. 2003. Behavioural development in the neonatal lamb: effect of maternal and birth-related factors. Theriogenology 59: 1027-1050.

Ferguson, M. B. et al. 2011. The wool production and reproduction of Merino ewes can be predicted from changes in liveweight during pregnancy and lactation. Animal Production Science 51: 763-775.

Fogarty, N., D. Hall, and P. Holst. 1992. The effect of nutrition in mid pregnancy and ewe liveweight change on birth weight and management for lamb survival in highly fecund ewes. Australian Journal of Experimental Agriculture 32: 1-10.

Greenwood, P. L., Thompson, A.N., Ford, S.P. . 2010. Postnatal consequences of the maternal environment and of growth in prenatal life for productivity of ruminants. In "Managing the prental environment to manage livestock productivity". . Springer Science + Business Media, Dordrecht, The Netherlands.

Gunn, R. G., J. M. Doney, and A. J. F. Russel. 1969. Fertility in Scottish Blackface ewes as influenced by nutrition and body condition at mating. The Journal of Agricultural Science 73: 289-294.

Gunn, R. G., and T. J. Maxwell. 1989. A note on the effect of the direction of live-weight change about the time of mating on reproductive performance of Greyface ewes. Animal Science 48: 471-474.

Jordan, D., and D. Mayer. 1989. Effects of udder damage and nutritional plane on milk yield, lamb survival and lamb growth of Merinos. Australian Journal of Experimental Agriculture 29: 315-320.

Joubert, D. M. 1972. Effect of season and plane of nutrition on post-parturient anoestrus in Dorper sheep. Agroanimalia 4: 19-24.

Kelly, R. W. 1992. Lamb mortality and growth to weaning in commercial Merino flocks in Western Australia. Australian Journal of Agricultural Research 43: 1399-1416.

Kenyon, P. R., P. C. Morel, and S. T. Morris. 2004. The effect of individual liveweight and condition scores of ewes at mating on reproductive and scanning performance. New Zealand veterinary journal 52: 230-235.

Kilminster, T. F., and J. C. Greeff. 2011. A note on the reproductive performance of Damara, Dorper and Merino sheep under optimum management and nutrition for Merino ewes in the eastern wheatbelt of Western Australia. Tropical Animal Health and Production.

Knight, T. W., Lynch, P.R., Hall., DRH., Hockey., H. 1988. Identification of factors contributing to lamb survivial in Marshal Romney sheep. New Zealand Journal of Agricultual Research 31: 259-271.

Lassoued, N., M. Rekik, M. Mahouachi, and M. Ben Hamouda. 2004. The effect of nutrition prior to and during mating on ovulation rate, reproductive wastage, and lambing rate in three sheep breeds. Small Ruminant Research 52: 117-125.

Lightfoot, R. J., Marshall, T, Croker, K.P. 1976. Effects of rate and duration of lupin grain supplementation on ovulation and fertility of Merino ewes. Proc. Aust. Soc. Anim. Prod. 11: 5.

Lindsay, D. R., Knight, T.W., Smith, J.W., Oldham, C.M. 1975. Studies in ovine fertility in agricultural regions of Western Australia: ovulation rate, fertility and lambing performance. Australian Journal of Agricultural Research 26: 189-198.

Mikolayunas, C. M. et al. 2008. Effects of Supplementation and Stage of Lactation on Performance of Grazing Dairy Ewes1. Journal of Dairy Science 91: 1477-1485.

Morgan, J. E., N. M. Fogarty, S. Nielsen, and A. R. Gilmour. 2006. Milk yield and milk composition from grazing primiparous non-dairy crossbred ewes. Australian Journal of Agricultural Research 57: 377-387.

Morgan, J. E., N. M. Fogarty, S. Nielsen, and A. R. Gilmour. 2007. The relationship of lamb growth from birth to weaning and the milk production of their primiparous crossbred dams. Australian Journal of Experimental Agriculture 47: 899-904.

Morley F.H.W., W. D. H., Kenney P.A., Davis I.F. . 1978. Predicting ovulation rate from liveweight in ewes. Agricultural Systems 3: 169.

Nottle, M. B., Hynd, P.I., Seamark, R.F., Setchell, B.P. 1988. Increases in ovulation rate in lupin-fed ewes are initiated by increases in protein digested post-ruminally. Journal of Reproduction and Fertility 84: 563-566.

Nottle, M. B., Kleeman, D.O., Seamark, R.F. 1997. Effect of previous undernutrition on the ovulation rate of Merino ewes supplemented with lupin grain. Animal Reproduction Science 49: 29-36.

Nottle, M. B., D. O. Kleemann, T. I. Grosser, and R. F. Seamark. 1997. Evaluation of a nutritional strategy to increase ovulation rate in Merino ewes mated in late spring-early summer. Animal Reproduction Science 47: 255-261.

Oldham, C. M. et al. 2011. The birthweight and survival of Merino lambs can be predicted from the profile of liveweight change of their mothers during pregnancy. Animal Production Science 51: 776-783.

Paganoni, B. L., M. B. Ferguson, G. A. Kearney, and A. N. Thompson. 2014. Increasing weight gain during pregnancy results in similar increases in lamb birthweights and weaning weights in Merino and non-Merino ewes regardless of sire type. Animal Production Science 54: 727-735.

Parr, R. D., IF; Squires, TJ; Miles, MA. 1992. Influence of lupin feeding before and after joining on plasma progesterone and fertility in Merino ewes. Proceedings of the Australian Society of Animal Production 19: 185-187.

Pearse, B. H. G., N. P. McMeniman, and I. A. Gardner. 1994. Influence of body condition on ovulatory response to lupin (Lupinus angustifolius) supplementation of sheep. Small Ruminant Research 13: 27-32.

Schoeman, S. J., and R. Burger. 1992. Performance of Dorper sheep under an accelerated lambing system. Small Ruminant Research 9: 265-281.

Schoeman, S. J., R. De Wet, and C. A. Van der Merwe. 1993. Assessment of the reproductive and growth performance of two sheep composites, developed from Finnish Landrace, compared to the Dorper. South African Journal of Animal Science 23: 207-209.

Silanikove, N. 2000. The physiological basis of adaptation in goats to harsh environments. Small Ruminant Research 35: 181-193.

Silva, A. M. A., A. G. Silva Sobrinho, I. A. C. M. Trindade, K. T. Resende, and O. A. Bakke. 2007. Net and metabolizable protein requirements for body weight gain in hair and wool lambs. Small Ruminant Research 67: 192-198.

Silva, A. M. A., A. G. S. Sobrinho, I. A. C. M. Trindade, K. T. Resende, and O. A. Bakke. 2004. Food intake and digestive efficiency in temperate wool and tropic semi-arid hair lambs fed different concentrate: forage ratio diets. Small Ruminant Research 55: 107-115.

Snyman, M. A., and W. J. Olivier. 2002. Productive performance of hair and wool type Dorper sheep under extensive conditions. Small Ruminant Research 45: 17-23.

Thompson, A. et al. 2011. Improving the nutrition of Merino ewes during pregnancy and lactation increases weaning weight and survival of progeny but does not affect their mature size. Animal Production Science 51: 784-793.

Thompson, A. N., Curtis, K.M.S. 1990. The effects of lupin or oat grain supplements on liveweight change, staple strength and position of break for sheep grazing dry annual pastures. . Proceedings of the Australian Society of Animal Production 18: 400-403.

Viñoles, C., K. M. M. Glover, B. L. Paganoni, J. T. B. Milton, and G. B. Martin. 2012. Embryo losses in sheep during short-term nutritional supplementation. Reproduction, Fertility and Development 24: 1040-1047.

Viñoles, C., A. Meikle, and G. B. Martin. 2009. Short-term nutritional treatments grazing legumes or feeding concentrates increase prolificacy in Corriedale ewes. Animal Reproduction Science 113: 82-92.

Viñoles, C. et al. 2010. The use of a 'first-wave' model to study the effect of nutrition on ovarian follicular dynamics and ovulation rate in the sheep. Reproduction 140: 865-874.

Wheeler, J., Reardon, T.F., Hedges, D.A., Rocks., R.L. 1971. The contribution of the conceptus to weight change in pregnant Merino ewes at pasture. Journal of Agricultural Science 76: 347-353.

Wilkes, M. J., P. I. Hynd, and W. S. Pitchford. 2012. Damara sheep have higher digestible energy intake than Merino sheep when fed low-quality or high-quality feed. Animal Production Science 52: 30-34.

Young, J. M., A. N. Thompson, M. Curnow, and C. M. Oldham. 2011. Whole-farm profit and the optimum maternal liveweight profile of Merino ewe flocks lambing in winter and spring are influenced by the effects of ewe nutrition on the progeny's surivial and lifetime wool production. Animal Production Science 51: 821-833.