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On-farm paddock-scale comparisons across southern Australia confirm that increasing the nutrition of Merino ewes improves their production and the lifetime performance of their progeny

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Abstract. Experiments conducted by Lifetimewool at plot-scale have shown that differences in the maternal liveweight during pregnancy and lactation (liveweight profiles) of individual Merino ewes influences their wool production and reproductive rate as well as the birthweight, survival, weaning weight and lifetime wool production of their lambs in a predictable manner. This study determined whether these impacts of nutrition of the ewe on ewe and progeny performance are measurable on commercial properties across southern Australia at a paddock-scale where ewes were aggregated into flocks with a greater spread of the date of conception and where the liveweight profile of the flocks were managed based on random samples of 100 ewes and liveweight was uncorrected for fleece weight or conceptus. Eighteen paddock-scale experiments at 15 sites were conducted in cooperation with wool producers across Victoria, Western Australia, New South Wales, South Australia, and Tasmania. Each co-operator joined up to 1000 mixed aged adult Merino ewes. The flock was scanned using ultrasound at Day 50 from the start of joining to identify those ewes that conceived during the first 21 days of joining. These ewes were then split at random into two treatments and fed to achieve a target difference in liveweight of 10 kg or ~1 condition score/fat score at lambing. The production of ewes during their year of pregnancy and following their next joining was measured as was the performance of their progeny up to their third shearing. Only the 13 paddock-scale experiments that achieved a difference in liveweight profile at lambing of at least 4 kg were included in the final analysis. In these 13 experiments, increasing the nutrition of Merino ewes during pregnancy clearly increased the clean fleece weight and fibre diameter in ewes and the survival and lifetime wool production of their lambs. In most cases the size of the effect was not significantly different to that predicted by the relationship derived using individual liveweight profiles in the plot-scale experiments. This confirms that managing average ewe liveweight or condition score/fat score profile through better nutrition will lead to predictable increases in the performance of ewes and their progeny performance under commercial conditions and validates the use of the plot-scale relationships in economic analyses.

Additional keywords: condition score, ewe nutrition, liveweight, wool production.

Introduction

The Merino ewe and her progeny are the productive unit in most wool-producing enterprises and achieving adequate nutrition for breeding ewes through efficient utilisation of grown pasture and supplement are fundamental to farm profitability. Plot-scale experiments conducted by Lifetimewool have shown that differences in the maternal liveweight (liveweight minus wool and conceptus) and change of maternal liveweight during pregnancy and lactation (liveweight profiles) of individual Merino ewes predictably influences their wool production and reproductive rate (Ferguson *et al.* 2011). In addition, the liveweight profile of ewes influences the birthweight and

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survival of their lambs (Oldham *et al*. 2011) as well as their weaning weight (Thompson *et al*. 2011*a*) and their clean fleece weight and fibre diameter during their lifetime (Thompson *et al*. 2011*b*). These ewe and progeny responses from the plot-scale work informed the bio-economic modelling by Young *et al*. (2011), which indicated that adoption of ewe management guidelines based on achieving specified liveweight profiles during pregnancy could lead to substantial improvements in whole-farm profit, particularly if achieved in conjunction with higher stocking rates.

It is well established that observed differences in performance in tightly controlled agronomic and animal experiments generally decrease when transferred to the farm scale (Davidson *et al*. 1967). Hence, to develop more confidence in and validate the efficacy of the ewe management guidelines developed by the Lifetimewool project (Curnow *et al*. 2011), the project established paddock-scale research sites in cooperation with wool producers across the main wool-producing regions of Victoria, Western Australia, New South Wales, South Australia, and Tasmania. Ewes at each site were managed to achieve high or low liveweight and condition or fat score profiles during pregnancy and at lambing to test the hypothesis that the principal effects observed for individual ewes within the Lifetimewool plot-scale research sites were measurable and of similar size when aggregated into average flock effects across a wide variety of environments and pasture systems using different Merino genotypes.

Materials and methods

All procedures reported in this paper were conducted according to the guidelines of the Australian Code of Practice for the Use of Animals for Scientific Purposes and received approval from the various Department of Agriculture Animal Ethics Committees.

Experimental sites

The experimental sites were established between 2003 and 2005 on commercial farms located in the main wool-producing regions of southern Australia (Fig. 1).

Site protocols

At each site, the co-operators mated ~1000 mixed aged adult Merino ewes to Merino rams in a single flock. The start of joining ranged from December at Dandaragan in Western Australia to April at Mandagery in New South Wales and was classified as Day 0 of each experiment. Ultrasound scanning of the ewes at Day 50 identified ewes that conceived during the first 21 days of joining as embryos can only be detected from Day 30 of pregnancy (C. M. Oldham, pers. comm.). This cohort of ewes was used so that the differential feeding treatments could start as soon as possible after conception, minimise the distribution of conception (fetal age), reduce the bias between farms and increase the ability to meet target liveweight profiles. From the ewes pregnant at Day 21, two random subsets of at

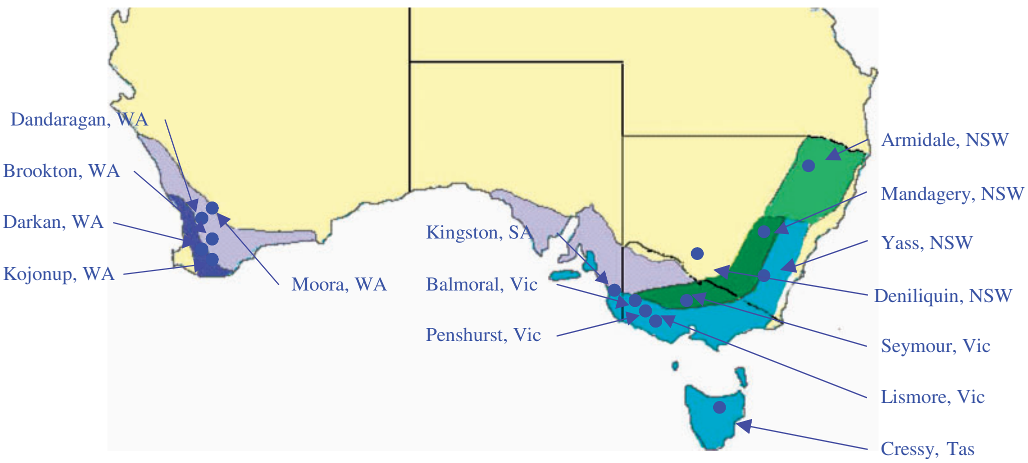

Fig. 1. Location of paddock-scale research sites across southern Australia. (■) Southern slopes New South Wales and north-central Victoria – this zone is characterised by a 6-month growing season and winter rainfall (450–600 mm) with a mix of annual grasses, perennial rye grasses and subterranean clover and a total pasture production of 6–8 t/ha. Typically these farm businesses have 30–50% crop. (■) High rainfall zone – this zone is characterised by 8-month growing seasons and winter rainfall (>550 mm) with a mix of annual grasses, perennial rye grasses and subterranean clover and a total pasture production of 6–8 t/ha. (■) Medium rainfall zone – this zone is characterised by winter rainfall (400–550 mm) and a 6-month growing season with a mix of annual grasses and subterranean clover. Due to a longer growing season than the cereal zone there are differences in pasture growth rates and total feed on offer produced. (■) Cereal–sheep zone – this zone is characterised by a 5-month growing season and winter rainfall (<400 mm) and hot summers with no effective rainfall. Crops form a substantial part of the farm business (up to 70%) and most properties have stubbles available for grazing. Pastures are predominantly a mix of annual grasses, subterranean clover and medics with a total pasture production of 2–5 t/ha per year. (■) Northern Tablelands sheep zone New South Wales – this zone is characterised by annual rainfall greater than 650 mm with marked summer incidence. The growing season is limited by warm to hot summers and cold winters with a long frost interval. The pastures are a mix of native summer active perennials with sub-clover that decrease in feed quality during winter and introduced perennial grasses with sub-clover. Total pasture production is typically between 6-9 t/ha per year.

least 350 ewes from the original flock were managed to achieve pre-determined liveweight and condition (Jefferies 1961) or fat score targets (O'Halloran *et al*. 1986) by lambing. Each subset of ewes had the same age structure, genetics, rams at joining, distribution of liveweight and condition score at joining.

The liveweight and condition score targets were based on the liveweight profiles of the high (condition score 3 and 3000 kg dry matter per hectare feed on offer) or the low (condition score 2 and 1100–1400 kg dry matter per hectare feed on offer) treatments of the plot-scale experiments (Ferguson *et al*. 2011). The aim of the methodology was to achieve a difference in liveweight between the high and low treatments of 10 kg by lambing. Ewes were re-scanned at ~Day 70 to identify single- and twin-bearing ewes within the high and low nutritional treatments and udder painting was used to identify single- and twin-born lambs at lamb marking using the method described by Davis *et al*. (1981) or a barrier porous to lambs but not ewes (J. Wilkins, pers. comm.) to identify single- and twin-born lambs at lamb marking. The ewes in the high and low nutritional treatments were recombined between lamb marking and weaning and run together until the following joining. At each site the treatments were not replicated.

Ewes were weighed and condition or fat scored monthly (on a random sample of 50 ewes from both single- and twin-bearing ewes in each nutritional treatment) using the same assessors wherever possible. Both condition and fat scoring techniques are highly repeatable (van Burgel *et al*. 2011). Depending on the collaborating farm, climatic conditions and feed on offer, supplementation with grain was used to manipulate liveweight and condition/fat score of each treatment group to meet the targets. GrazFeed was used to assist feed budgeting decisions to meet the liveweight and condition or fat score targets (Donnelly *et al*. 2002).

Ewes were also scanned for pregnancy status and litter size 70–90 days after the commencement of the following joining to determine the carryover effects on reproductive performance of the nutritional treatments and their previous pregnancy status. The lambs from both nutritional treatments were run together until their hogget shearing. Subsequently, the ewe and wether progeny were separated and run according to the collaborator's normal management.

Measurements

Ewes were weighed and condition scored immediately from the paddock at monthly intervals and when other measurements were made. At the three sites in New South Wales fat score was used rather than condition score. Feed on offer was estimated by a single observer using pasture cuts to calibrate visual estimates (Ferguson *et al*. 2011). Nutritive value of the supplements and the pasture was analysed by near-infrared spectroscopy analysis according to the procedures outlined by Smith and Flinn (1991) to assist with feed budgeting decisions.

Midside samples of wool (~50 g) were collected before shearing. Washing yield, mean fibre diameter, staple length and staple strength were measured in a commercial laboratory using Australian Standard methods. Greasy fleece weight was measured at shearing. The fleece weight, fibre diameter, staple length and staple strength of wool was measured on a random sample of single- (n = 25) and twin-bearing (n = 25) ewes from each nutritional treatment.

Lamb liveweight was measured at marking, weaning, 12 months of age and at each shearing. The clean fleece weight, fibre diameter, staple strength and length of wool produced by a random sample of 100 single progeny and all possible twin progeny in each nutritional treatment was measured at their first (lamb), second (hogget) and third (adult) shearing. Ewe progeny were also mated and scanned after their maiden joining. Lamb survival to marking was quantified as the number lambs present at marking as a proportion of the number of lambs scanned.

Statistical analyses

Some sites continued for more than 1 year providing a second mating and lambing cycle under the experimental design. The second year at each site was nominally designated as another experiment as all the ewes (n ~1000) were re-randomised to the nutritional treatments.

Differences in liveweight and condition or fat score between the high and low nutritional treatments were calculated for each monitoring point to determine the success at each site in achieving the high and low nutritional treatments. After Day 70, when there was liveweight and condition or fat score data for both twin- and single-bearing ewes, the treatment difference was estimated as the average of the difference between the high and low nutritional treatments for both the single- and twin-bearing ewes. The criteria for assessing success in implementation of the experimental protocol at each experimental site was a difference in the average liveweight of at least 4 kg between the two treatment groups by Day 140 of the experiment and that the number of monitoring points was complete.

All statistical analyses were performed using GENSTAT 10th Edition (GENSTAT Committee 2007). ANOVA was conducted across sites for sites that showed a consistent and sufficient difference in liveweight and condition score or fat score during pregnancy. The analysis used mean site data, with site and treatment within site as the blocking terms and level of nutrition during pregnancy and birth type plus their interaction as treatment terms. It was appropriate to perform ANOVA without data transformation as statistically these means for each site are over a large number of sheep and thus by the central limit theorem have an approximate normal distribution. There were no significant interactions between nutritional treatment and pregnancy status of the ewe or rear type of the lamb so most results presented on ewe and progeny performance are the means of the treatments (high and low or single and twin) for each of the production variables of both ewes and their progeny. These differences in production of ewes and their progeny between treatments were also regressed against the difference in liveweight between treatments at Day 140 of pregnancy. This was done to estimate the size of the effects at the paddock-scale to compare the effects observed against those in the more tightly controlled plot-scale experiments (Ferguson *et al*. 2011; Oldham *et al*. 2011; Thompson *et al*. 2011*a*, 2011*b*).

Results

Ewe liveweight and condition or fat score

The treatment differences in ewe liveweight and condition or fat score over time are summarised in Fig. 2. On average a change of 1 condition score was equivalent to ~9.2 kg liveweight (van Burgel *et al.* 2011). Based on the criteria for assessing successful implementation of the experimental protocol, five experiments (Site 1, Site 3 Year 2, Site 7, Site 11, Site 15 Year 2) were excluded from further analysis.

The treatment differences in ewe liveweight and condition score during pregnancy at the remaining 13 sites followed similar patterns. These differences were not significant at Day 21, increased steadily to Day 140 and then declined from the

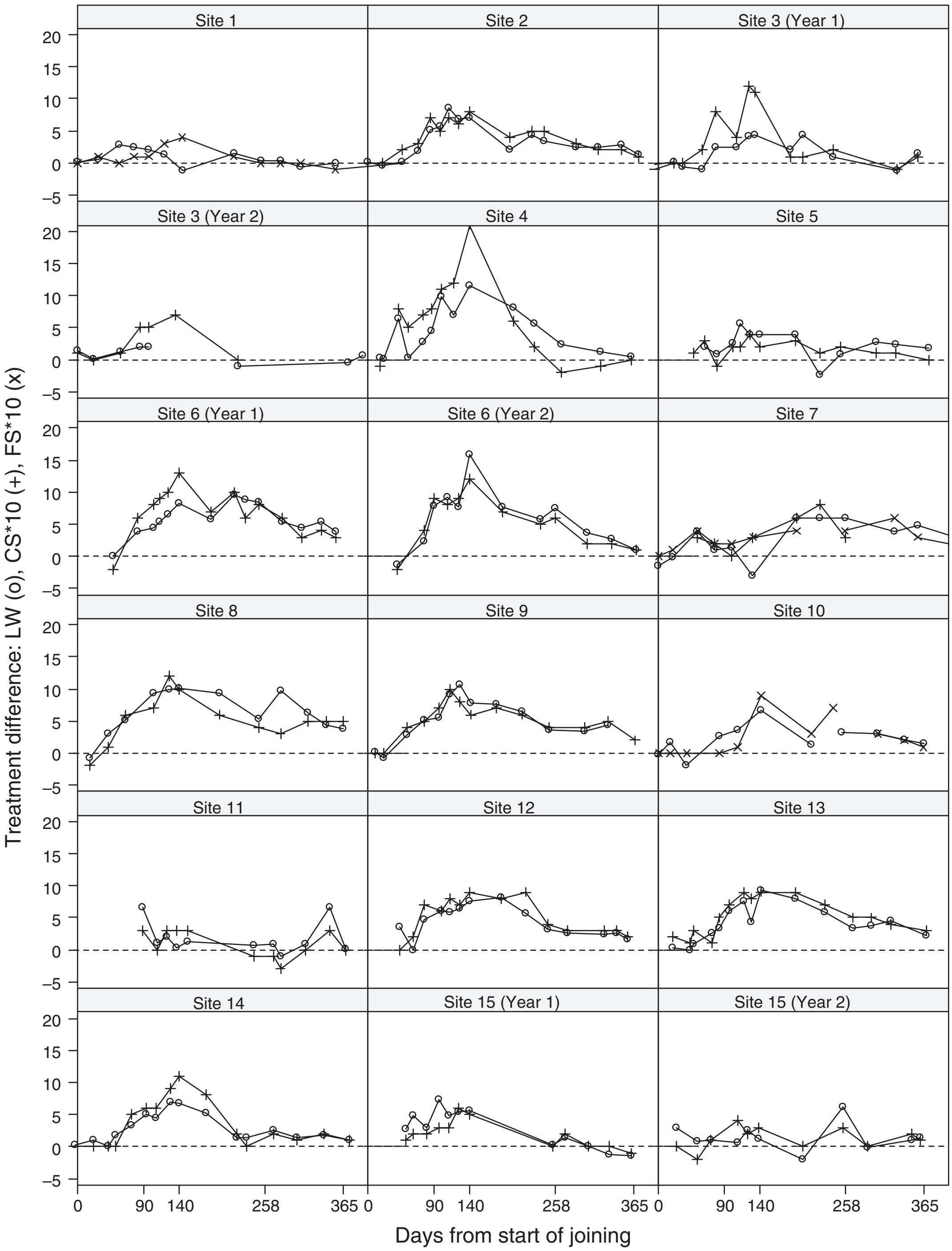

Fig. 2. Trellis graphs showing the average difference between high and low nutrition treatments during pregnancy for liveweight (LW, ○), condition score (CS, +) or fat score (FS, ×) for 18 paddock-scale experiments.

commencement of lambing onwards. For these 13 sites the average difference in liveweight of the ewes between the high and low nutrition treatments was 6 kg at Day 98 and 8 kg at Day 140 before narrowing to less than 4 kg by Day 258. Differential management of ewe nutrition during pregnancy also resulted in a difference ($P < 0.001$) of about 1 condition score at lambing between the high and low nutrition treatments (Table 1). Ewe condition score at Days 98 and 140 was similar for single- and twin-bearing ewes, but the twin-bearing ewes were heavier ($P < 0.001$).

Ewe wool production and characteristics

Ewe clean fleece weight, fibre diameter, staple length and staple strength all differed significantly ($P < 0.05$) between nutritional treatments and pregnancy status (Table 1). On average, higher nutrition during pregnancy resulted in heavier fleece weight, broader fibre diameter, longer staple length and higher staple strength. Single-bearing ewes produced more wool that had longer staple length and greater staple strength than twin-bearing ewes, but the differences in mean fibre diameter between single- and twin-bearing ewes were not significant.

Carryover reproductive performance of ewes

There was no significant effect of nutritional treatment during the previous pregnancy on the subsequent carry over reproductive rate. Ewes on the high nutrition treatment had a mean reproduction rate of 132% compared with 126% for ewes on low nutrition ($P = 0.08$). There were relatively small differences between nutritional treatments in ewe liveweight and condition score at the following joining (Day 365) with high treatment ewes being 54.2 kg, at condition score 3.2 compared with low treatment ewes 52.4 kg, condition score 3.0 ($P < 0.05$).

Lambs scanned *in utero* at the following joining was significantly influenced by pregnancy status in the previous year ($P < 0.001$) with twin-bearing ewes scanning at 138% compared with singles at 121%. At their carryover joining, ewes that were twin-bearing in the previous year were 0.1 lower in condition score (3.1 vs 3.2, $P < 0.001$) but 1 kg heavier (53.8 kg vs 52.8 kg, $P < 0.01$) than ewes that had been single-bearing in the previous year.

Progeny performance

Lamb survival and reproductive performance

Lamb survival to marking was influenced ($P < 0.01$) by ewe nutritional treatment during pregnancy and birth type. On average across sites, lambs from ewes under the high nutrition treatment had 81% survival to marking compared with 71% for low nutrition. Twin-born lambs were also less likely to survive to marking with an average survival of 64% compared with 88% for single-born lambs. These differences in survival were reflected at lamb marking where ewes receiving high nutrition during pregnancy achieved 116% lambs marked compared with ewes on low nutrition at 100% ($P < 0.001$). Likewise single-bearing ewes achieved a lamb marking percentage of 88% compared with 128% from twin-bearing ewes ($P < 0.001$). While there was no significant interaction between pregnancy status and nutritional treatment for either survival to marking ($P = 0.2$) or lamb marking percentage ($P = 0.1$), the effect of nutrition on survival and marking percentage was greater in the twins. Twin-bearing ewes in the high nutrition group had 71% of their lambs survive and therefore marked 142% compared with 57 and 115%, respectively, for twins from the low nutrition treatment.

Maternal nutrition during pregnancy had no significant effect on the reproductive performance of ewe progeny as maidens (95 vs 96% for high and low nutrition, respectively, $P = 0.8$). Ewe progeny that were born a twin tended to have slightly higher reproductive rate ($P = 0.03$) scanning 98% compared with 94% for single-born progeny.

Progeny liveweight

The liveweight of progeny at weaning and 6 months of age was influenced ($P < 0.05$) by ewe nutritional treatment during pregnancy (Table 2). The liveweight of single progeny at weaning, 6 months and 12 months of age was higher than twin progeny ($P < 0.001$). These differences in the liveweight of progeny reduced over time.

Progeny wool production and fibre diameter

The amount of greasy and clean fleece wool produced at the first shearing (4–10 months of age) was greater ($P < 0.05$) for

Table 1. Treatment means for ewe production variables across 13 Lifetimewool paddock-scale experiments in southern Australia
* significant difference ($P < 0.05$)

Ewe production variable	Nutrition High	Nutrition Low	l.s.d. ($P = 0.05$)		Pregnancy Single	Pregnancy Twin	l.s.d. ($P = 0.05$)	
Condition score Day 0	2.62	2.64	0.04	–	2.61	2.66	0.06	–
Condition score Day 98	3.02	2.42	0.17	*	2.70	2.74	0.04	*
Condition score Day 140	3.21	2.26	0.28	*	2.76	2.70	0.05	*
Liveweight Day 0 (kg)	49.0	49.0	0.2	–	48.6	49.5	0.6	*
Liveweight Day 98 (kg)	53.1	47.2	1.4	*	48.5	51.8	0.5	*
Liveweight Day 140 (kg)	60.1	52.0	1.9	*	53.7	58.5	0.5	*
Clean fleece weight (kg)	3.5	3.1	0.1	*	3.4	3.2	0.1	*
Mean fibre diameter (μm)	20.8	20.0	0.4	*	20.4	20.4	0.2	–
Staple length (mm)	95.1	91.2	2.4	*	93.9	92.3	1.1	*
Staple strength (N/ktex)	35.3	31.7	3.2	*	34.6	32.4	1.6	*

Table 2. Treatment means for progeny production variables across 13 Lifetimewool paddock-scale experiments in southern Australia
* significant difference ($P < 0.05$)

Progeny production variable	Nutrition High	Nutrition Low	l.s.d. ($P = 0.05$)		Pregnancy Single	Pregnancy Twin	l.s.d. ($P = 0.05$)	
Liveweight weaning (kg)	23.6	21.9	1.5	*	24	21.5	0.7	*
Liveweight 6 months (kg)	29.5	28.3	0.8	*	29.5	28.4	0.4	*
Liveweight 12 months (kg)	32.5	31.7	1.0	–	32.6	31.6	0.4	*
Lamb clean fleece weight (kg)	1.58	1.48	0.07	*	1.61	1.45	0.04	*
Hogget clean fleece weight (kg)	2.89	2.83	0.06	*	2.94	2.78	0.06	*
Hogget mean fibre diameter (μm)	18.28	18.41	0.11	*	18.20	18.49	0.13	*
Adult clean fleece weight (kg)	3.14	3.10	0.06	–	3.19	3.05	0.06	*
Adult mean fibre diameter (μm)	18.61	18.77	0.17	–	18.61	18.76	0.14	*

progeny from ewes on a higher plane of nutrition during pregnancy and for single compared with twin-born progeny (Table 2). However, there were no significant effects on fibre diameter or any other wool traits at the first shearing (data not shown).

Clean fleece weight at the hogget (second shearing) was affected by birth type ($P < 0.001$) and nutritional treatment ($P < 0.05$). Likewise fibre diameter at the second shearing was greater ($P < 0.001$) for twin progeny and progeny produced by ewes that had received lower nutrition ($P < 0.05$) during pregnancy. The effect of maternal nutrition equated to ~60 g of clean wool and 0.13 microns in fibre diameter (Table 2). The effect of being either a twin- or single-born progeny was approximately double, with the difference being 160 g of clean wool and 0.29 microns in fibre diameter.

The fleece weight of progeny at the third shearing was greater ($P < 0.001$) for singles than twins, but ewe nutrition did not affect clean fleece weight ($P = 0.2$; Table 2). Mean fibre diameter at the third shearing of the progeny was affected by birth type ($P < 0.05$) and ewe nutrition during pregnancy ($P = 0.07$). The differences in progeny wool characteristics between nutrition treatments became non-significant at adult age whereas the differences in wool characteristics due to birth rank remained significant.

Comparison between the paddock- and plot-scale experiments

In the paddock-scale experiments a 10-kg difference in ewe liveweight at lambing resulted in differences in ewe wool production of ~0.43 kg in clean fleece weight, 1.0 micron in fibre diameter, 5 mm in staple length and 5 N/ktex in staple strength (adapted from Table 3). This difference in liveweight of the ewe at lambing also resulted in a 10% unit difference in lamb survival to marking and ~2-kg difference in progeny weaning weight flowing on to a 1-kg difference at 12 months of age. Likewise a 10-kg difference in ewe liveweight resulted in progeny differences of ~70 g in clean fleece weight and 0.2 microns in fibre diameter (averaging the effects of the hogget and adult shearing data).

The effects of a difference of 10 kg in liveweight of individual ewes at Day 140 of pregnancy on ewe and progeny production traits predicted using the published relationships derived from the plot-scale experiments are shown in Table 3. In general the realised effects in the paddock-scale experiment were smaller but not significantly so than the effects that were predicted from the plot-scale relationships derived from the liveweight profile of individual ewes to Day 140 of pregnancy.

Table 3. A comparison of the predicted effects in the paddock-scale experiments of a 10-kg difference in liveweight of flocks at Day 140 after joining (Day 0) for the 13 paddock-scale sites versus the predicted effects on the same traits of individual ewes using the published relationships for the liveweight profile of the ewes in the plot-scale experiments
* paddock-scale effects that are different from the predicted plot-scale effects ($P < 0.05$)

	Paddock-scale Effect	Paddock-scale s.e.	Plot-scale[A] Effect	Plot-scale[A] s.e.
Ewe clean fleece weight (kg)	0.43*	0.06	0.61[D]	0.05
Ewe fibre diameter (μm)	0.96	0.21	1.09[D]	0.11
Ewe staple strength (N/ktex)	4.62	1.58	5.90[D]	0.59
Ewe staple length (mm)	4.67	1.25	2.38[D]	0.82
Ewe carryover scanning[C]	0.06	0.04	–	–
Lamb survival to marking[C]	0.10	0.03	–	–
Progeny liveweight at weaning (kg)	2.27	0.72	1.83[E]	0.22
Progeny liveweight at 12 months (kg)[B]	1.06	0.48	1.59[F]	0.34
Progeny hogget clean fleece weight (kg)	0.08	0.03	0.15[G]	0.04
Progeny hogget fibre diameter (μm)	–0.15*	0.06	–0.35[H]	0.09
Progeny adult clean fleece weight (kg)	0.05*	0.03	0.17[G]	0.05
Progeny adult fibre diameter (μm)	–0.23	0.08	–0.46[H]	0.26

[A]Average of WA and Vic. effects, except for staple length (WA only) and 3rd shearing clean fleece weight (Vic. only).
[B]Plot-scale comparison is for 15 months.
[C]Equations not available for the plot-scale effects.
[D]Adapted from Ferguson *et al.* (2011) tables 5 and 6.
[E]Adapted from Thompson *et al.* (2011*a*) table 2.
[F]Adapted from Thompson *et al.* (2011*a*) tables 3 and 4.
[G]Adapted from Thompson *et al.* (2011*b*) tables 6 and 7.
[H]Adapted from Thompson *et al.* (2011*b*) tables 8 and 9.

Discussion

This study across 13 paddock-scale experiments validates the predictive equations generated in the plot-scale experiments relating the nutrition of ewes during pregnancy to the productivity of the ewe and their progeny until at least their third shearing. Further it justifies their use as the basis of new nutritional guidelines for the management of commercial flocks of Merino ewes. In the paddock-scale experiments increasing the nutrition of merino ewes during pregnancy clearly increased the clean fleece weight and decreased the fibre diameter of wool produced by their progeny to at least their second adult shearing. The same trends were evident at the third shearing. In addition, the same nutritional treatments influenced the amount and quality of wool produced by the ewes and the survival and weaning weight of their progeny. The influence of maternal nutrition was similar to that found in the intensive highly controlled plot-scale experiments (Ferguson *et al*. 2011; Oldham *et al*. 2011; Thompson *et al*. 2011*a*, 2011*b*). This is a vital finding as it was reasonable to expect a significant discounting of the relationships with the increase in scale as previously reported by Davidson *et al*. (1967). In the paddock-scale experiment there was a greater spread of the date of conception (±10 days in the paddock-scale compared with ±1 day in the plot-scale experiments). The treatment liveweight profiles were based on the average of a random sample of 100 ewes (50 single-bearing and 50 twin-bearing ewes) out of a group of ~350 ewes at the key weigh points of joining scanning and pre-lambing vaccination compared with the repeat weighing of individual ewes in the plot scale experiments.

Coupled with the fact that the larger and longer term difference in the performance of twin progeny compared with single progeny (Hocking Edwards *et al*. 2011; Oldham *et al*. 2011; Thompson *et al*. 2011*a*, 2011*b*) also indicate that this maternal effect through either nutritional management of the ewe or litter size are real and must be factored into economic analyses of the impacts of nutritional guidelines on whole-farm profit (Young *et al*. 2011).

Lamb survival was significantly greater at lambing for ewes receiving higher nutrition during pregnancy. This is consistent with impact of liveweight change on the lamb birthweight and on survival of both the ewe and lamb (Oldham *et al*. 2011). Twin-born lambs had significantly lower survival, which is consistent with known literature and the evidence from the plot-scale studies (Oldham *et al*. 2011). A difference in ewe liveweight of 10 kg also resulted in an ~10% unit difference in lamb survival to marking. This difference in lamb survival is significant and sufficient to substantially modify lamb marking percentages. For example, the average lamb marking percentage for twin-bearing ewes reduced from 142 to 115% under low nutrition. Across all 13 sites the average lamb marking percentage under high nutrition was 116% compared with 100% under low nutrition. It is notable that similar levels of improvement have been observed in flocks of participant farms in Lifetime Ewe Management program (Trompf *et al*. 2011). In addition, improved ewe nutrition during pregnancy also resulted in lambs that were 2 kg heavier at weaning, and this would be expected to influence weaner survival (Thompson *et al*. 2011*b*). The possible additional contribution of the change in weaning weight and survival to whole-farm income and profitability was not considered in the analysis by Young *et al*. (2011).

In the year following the nutritional treatments, twin-bearing ewes achieved 17% more lambs in utero than single-bearing ewes despite a slightly lower condition score. This was to be expected given the repeatability of twinning of 0.11 (Hatcher *et al*. 2010). This suggests that in addition to the benefits of differential management between scanning and lambing (Young *et al*. 2008; Oldham *et al*. 2011; Thompson *et al*. 2011*a*), it might pay to preferentially manage twin-bearing ewes to increase their level of nutrition post weaning to set them up for the next joining.

Five of the 18 paddock-scale sites were removed from the final analysis because they failed to achieve a difference in the liveweight profile of the two nutritional treatment groups at lambing of greater than 4 kg. However, it should be noted that three of these sites were significantly affected by drought during the experimental period and this probably affected the success of nutritional management in these cases.

The paddock-scale studies were conducted at a commercial scale. When experimental targets were achieved the results from these experiments confirm those from the plot-scale experiments and have given sheep producers more confidence that these effects will be repeated on their farms. Further, the imperative of validating the plot-scale results at a paddock-scale has been borne out by the level of adoption shown by participants in Lifetime Ewe Management (Jones *et al*. 2011; Trompf *et al*. 2011) and sustained demand for the decision tools (Curnow *et al*. 2011; Jones *et al*. 2011).

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