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Mineral supplementation of lambing ewes grazing dual-purpose wheat

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Lambing ewes were grazed on dual-purpose wheat in two experiments in 2010 and 2011 with or without access to a mineral supplement. The calcium, magnesium and sodium content of wheat forage was below the requirements of ewes during late pregnancy and lactation, however no clinical cases of hypocalcaemia or hypomagnesaemia were observed in either experiment. Blood serum assays identified eight hypocalcaemic ewes and one hypomagnesaemic ewe in Experiment 1, and one hypocalcaemic ewe in Experiment 2, and the provision of a mineral supplement comprising of magnesium oxide, calcium carbonate and coarse salt had no effect on blood magnesium, total calcium, phosphorus or sodium. Lamb birthweight and survival were not affected by provision of the mineral supplement in either experiment, however the growth rate to marking (mean 38 ± 10 days of age) of twin-born lambs was higher in Experiment 1 when the supplement was provided to ewes grazing wheat (259 vs 243 g/head.day; $P = 0.002$).

Introduction

Dual-purpose wheat enables farmers to sow early and utilise the additional dry matter (DM) production for livestock feed and also harvest a grain crop later in the season (McMullen and

Virgona 2009). The advantages of dual-purpose wheat have been enhanced by the development of hard-grain varieties, which provide higher returns from sale of grain (Virgona *et al*. 2006) and the impact of grazing on grain yield can be minimised by removal of grazing livestock from crop paddocks before stem elongation (McMullen and Virgona 2009).

Wheat forage has a high nutritive value in terms of digestibility and protein (Dove and McMullen 2009), and quality is comparable to the live component of mixed pastures commonly available during winter in southern Australia (e.g. see Robertson *et al*. 2011). Macro-mineral deficiencies may be an issue with grazing wheat; however, supplementation with sodium (Na) and magnesium (Mg) has been shown to increase lamb growth rates when grazing wheat in Australia (Dove and McMullen 2009). No response to supplementation with limestone was observed in the same study where mean forage calcium (Ca) concentration ranged from 0.30 to 0.35% DM (Dove and McMullen 2009); although other recent studies have reported mean Ca content as low as 0.20% DM for dual-purpose wheat (Dove *et al*. 2012). The Mg concentrations for wheat forage in recent reports range from 0.10 to 0.27% DM (Dove 2007; Dove and McMullen 2009; Miller *et al*. 2010; Dove *et al*. 2012); levels that are at worst marginal compared with the requirements of growing lambs (CSIRO 2007; Dove and McMullen 2009). Sodium concentrations from the same studies ranged from 0.002 to 0.08% DM compared with sheep requirements of 0.07 to 0.09% DM (CSIRO 2007), suggesting that Na will often be below the requirements of sheep grazing wheat. Furthermore the potassium (K) content of wheat forage is commonly high, ranging from 2.7 to 5.6% DM in the above reports, and this high K and low Na content can be expected to result in a high K : Na ratio in ruminal fluid, which can reduce Mg absorption from the rumen (Martens *et al*. 1987; Khorasani and Armstrong 1990).

While low bioavailability of Mg may reduce the productivity of growing lambs grazing wheat forage, the effect on late-pregnant and lambing ewes grazing wheat is unknown. Magnesium requirements increase to 0.12% DM in lactating ewes and there is a continuous loss of Mg in milk (CSIRO 2007; Suttle 2010). Transfer of Ca to the growing fetus and milk results in a negative Ca balance in ewes during late pregnancy and early lactation (Braithwaite *et al*. 1970), and the recommended dietary Ca allowance increases for late-pregnant and lactating ewes (CSIRO 2007). Mineral deficiencies are implicated in some metabolic diseases of reproducing livestock, and hypomagnesaemia (grass tetany) has been identified as an important cause of losses in mature cows grazing wheat pasture in the southern Great Plains of the USA (Bohman *et al*. 1983). An early report of high ewe mortality rates in northern New South Wales (NSW) associated with grazing wheat crops and other lush pastures suggested that grass tetany and hypocalcaemia were important (Blumer *et al*. 1939), however there is little information on the implications of utilising wheat pasture for ewes during late pregnancy and lactation under Australian conditions.

The aim of this study was to investigate the suitability of dual-purpose wheat for grazing by late-pregnant and lactating ewes, identify any metabolic diseases associated with grazing ewes on wheat and assess whether providing a basic mineral supplement, designed to correct the expected deficiencies in wheat forage, would prevent metabolic diseases and improve the growth rates of suckling lambs. It was hypothesised that lambing ewes grazing on dual-purpose wheat are more susceptible to hypomagnesaemia and hypocalcaemia due to deficiencies in Mg, Na and Ca in the wheat pasture, and that provision of a mineral supplement will assist to prevent the occurrence of these diseases.

Methods

Experiment 1 and Experiment 2 were undertaken with collaborating producers on commercial farms in southern NSW. Both experiments fitted within the normal system for both producers in terms of crop establishment, sheep husbandry, supplementation with grain and the timing of crop grazing by sheep, given the prevailing seasonal conditions in that year. Experiments were approved by the Charles Sturt University Animal Care and Ethics Committee (protocol numbers 10/050 and 11/027).

Experiment 1

The experiment was conducted in 2010 near Balldale in southern NSW (35°47’29.05”S, 146°31’50.05”E; 150 m altitude). Average annual rainfall for the district is 502.5 mm (BOM 2011).

Paddock preparation

The paddock [Red Sodosol (Isbell 2002)] was sown to lupins in 2009, with chemical weed control in January and April 2010. A soil test in March 2010 identified a soil pH_{Ca} of 5.2. Gypsum was spread at a rate of 1.25 t/ha in March 2010. Dual-purpose wheat (cultivar EGA Wedgetail) was sown on 16 April at a rate of 70 kg/ha with row spacing of 30 cm. Monoammonium phosphate (MAP) fertiliser was applied at sowing at a rate of 70 kg/ha. A portion of the paddock was subdivided into six plots of size 4.3 ha before the commencement of grazing.

Sheep management and measurements

Merino ewes (3–6 years) were joined to Merino rams in late January 2010. Ewes were shorn in late March and 292 ewes [mean weight 63.3 ± 4.8 kg; body condition score (BCS) 3.15 ± 0.34, Jefferies 1961] were pregnancy scanned in lamb by trans-abdominal ultrasound on 16 April, at which time they were identified as carrying either one or two fetuses. Ewes were drenched in late April (Valbazen, Coopers Animal Health, Bendigo East, VIC, Australia) and maintained on pasture until grazing of crop commenced. Prior to grazing the wheat crop, ewes were supplemented with wheat grain by trailing grain in the paddock at a rate of ~1 kg/head.week (offered three times per week).

Ewes were allocated to plots on 17 June at a stocking rate of 11.4 ewes/ha (49 or 47 ewes/plot depending on area of wheat, consisting of eight ewes scanned as twin-bearing and the balance having been identified at scanning as single-bearing ewes). All plots were grazed concurrently. The 48 twin-bearing ewes and a subsample of 48 single-bearing ewes were weighed and condition scored (Jefferies 1961). These ‘subsample’ ewes were blocked by BCS and randomly allocated to plots. Ewes in three plots were provided access *ad libitum* to a loose-lick supplement containing magnesium oxide (Causmag AL7), calcium carbonate (finely ground limestone) and coarse salt in a ratio of 2 : 2 : 1 (as-fed). Supplement was weighed and mixed by hand, and placed in feeders. The supplement was checked daily, with additional supplement added after all supplement previously provided had been consumed. The amount of supplement fed out in each plot was recorded and apparent consumption of supplement estimated based on the number of ewes per plot. The three control plots were not provided a supplement.

Lambing commenced on 18 June, with lambing rounds conducted from that time. Lambing rounds commenced at 0900 hours daily and were generally completed by 1200 hours. All lambs that had been born in the preceding 24 h were caught, weighed and tagged, and had their sex and birth status (single, twin or triplet) recorded. The weight was recorded as birthweight.

Sheep were yarded weekly during the experiment to take measurements from ewes and lambs. Measurements commenced from 0800 hours and were taken within 1 h of sheep being removed from the paddock, with no fasting period, and sheep were immediately returned to the appropriate plot. The 16 ewes (eight twin-bearing; eight single-bearing) in each plot that were identified as subsample ewes were body condition scored and weighed weekly. From the subsample group, blood samples were taken from five single-bearing and five twin-bearing ewes in each plot on four occasions corresponding to the start of the trial, after 7 days grazing crop (if still pregnant), and at the weigh dates occurring in the first week and fourth week of lactation; samples were taken from the same ewes on each occasion. Samples (5 mL) were taken from the jugular vein using a gel-separator vacutainer, with vacutainers immediately placed on ice. Samples were centrifuged within 5 h of sampling at 1850 *g* at room temperature for 20 min or until serum and plasma was separated, and vacutainers then returned to ice for analysis the following day.

All lambs were weighed weekly on Ruddweigh sheep scales to determine growth rates. The final weight was recorded on 12 August, which was the day before lamb marking and also the day that all ewes and lambs were removed from the plots and returned to pasture. This final lamb weight was recorded as marking weight. Mean age of single-born lambs at marking (*n* = 198) was 39 ± 10 days and twin-born lambs (*n* = 101) was 38 ± 10 days.

Experiment 2

Experiment 2 was conducted in 2011 at Cookardinia in southern NSW (35°36’37.45”S, 147°16;37.06”E; 262 m altitude). Long-term average annual rainfall for the district is 632 mm (BOM 2011). This property was selected to provide a contrast to the 2010 study, being in a higher-rainfall zone with a different genotype of sheep and management regime. Pregnancy scanning identified predominantly multiple fetuses so only twin-bearing ewes were selected for the experiment.

Paddock preparation

The soil type was a Red Sodosol. Due to technical difficulties no soil test was available however previous experiments on this property had recorded a surface soil pH_{Ca} of 5.3 in the wheat rotation (see Virgona *et al*. 2006). Lime had been applied at a rate of 2.5 t/ha in 2010 before the paddock was sown to canola. Trifluralin was applied as a pre-emergence herbicide in 2011, and the paddock sown in April 2011 to dual-purpose wheat (cultivar EGA Wedgetail) at a rate of 75 kg/ha with row spacing of 22.5 cm. MAP fertiliser was applied at sowing at a rate of 70 kg/ha. The paddock was subdivided into six plots of 2.2 ha before the commencement of grazing.

Sheep management and measurements

Crossbred ewes (Coopworth × Merino; 3 years old) were joined to Poll Dorset rams from 19 February 2011. Ewes were shorn on 10 May and pregnancy scanned in lamb by ultrasound on

18 May, at which time 144 ewes (weight 53.9 ± 4.9 kg; BCS 2.9 ± 0.3) were identified as carrying two fetuses. From scanning until the commencement of grazing the wheat crop ewes were grazing pasture and had *ad libitum* access to a loose-lick mineral supplement consisting of MgO, lime and salt, and were supplemented with faba beans (see Table 2 for nutritive value) twice weekly by trailing supplement along the ground at a rate of 1 kg/head.week before moving onto the wheat paddock. Supplementation with faba beans was continued for the first 1.5 weeks of the grazing experiment at the same rate. Prior to grazing dual-purpose wheat the ewes were grazing a pasture consisting of green annual ryegrass and clover as well as dry standing feed.

On 23 June ewes were treated with a combination drench (Hat-Trick, Ancare Australia, Parramatta, NSW, Australia), vaccinated (5-in-1), and randomly allocated into six plots. Ewes in each plot were condition scored at the commencement of the experiment and blood samples were taken from a subsample of five ewes in each plot (all BCS 3); blood samples taken during the experiment were from the same five ewes in each plot (‘subsample’ ewes). Stocking rate was 11 ewes/ha (24 ewes/plot).

Ewes were monitored daily during the first 3 weeks of the experiment. On 13 July ewes were yarded and body condition scored, and blood samples taken from the subsample group. Lambing commenced on 15 July, after which time daily lambing rounds were conducted with lamb measurements taken as per Experiment 1. In Experiment 2 ewes were given a score based on mothering ability on a scale of 1 – 5 (O’Connor *et al.* 1985). Sheep were yarded weekly to take blood samples from all subsample ewes, and to weigh lambs. Final weigh date of lambs was 23 August, at which time sheep were removed from the paddock; ewes were body condition scored and lambs were marked. Mean age of lambs at marking (n = 208) was 24 ± 8 days.

Pasture measurements

Feed on offer (FOO, kg DM/ha) in each plot was measured using the method described by Haydock and Shaw (1975). Calibration samples (n = 10–20) were selected on each sample date in a 0.45-m^2 quadrat. Visual assessments (n = 100 per plot) were then made using the 0.45-m^2 quadrat along diagonal transects across each plot. Calibration quadrats were harvested with hand-shears at a height of 1 cm above ground level. Calibration samples were dried at 80ºC, weighed to determine DM per square metre, and fitted to a calibration curve. All visual assessments were then converted to a DM mass per hectare based on this calibration curve.

Estimates were made every 2 weeks during Experiment 1 and every 3 weeks during Experiment 2.

Samples for proximate and mineral analysis were collected from each plot before the start of grazing and at the approximate midpoint of the lambing period using the toe-cut method (Cayley and Bird 1996). A sample was collected from each plot by taking 10 cuts using hand shears at a height of 1 cm above ground level. Samples were placed in sealable plastic bags and frozen. After thawing, samples were weighed, dried at 80°C, and then re-weighed to calculate the DM content of green forage. Samples were then ground through a 1-mm sieve. Proximate analysis were determined by near-infrared spectroscopy with a Bruker multi-purpose analyser (Bruker Optik GmbH, Ettlingen, Germany) and calibration curves as described by Packer *et al.* (2011). Methodology for preparation of plant samples for mineral analysis was as described by Miller (1998). Mineral concentrations in forage were used to calculate the tetany index according to the equation:

% potassium × 256/(% calcium × 499 + % magnesium × 823), (Kempt and ‘t Hart 1957).

Serum analyses

Serum mineral concentrations were analysed using a biochemistry analyser (Thermo Konelab 30i). Ewes with serum Mg below 18.0 mg/L (0.73 mmol/L) were classified as hypomagnesaemic (Todd 1969; McCoy *et al.* 2001) and serum Ca below 80 mg/L (2.0 mmol/L) were classified as hypocalcaemic (Franklin *et al.* 1948).

Statistical analyses

In Experiment 1, two ewes that had been identified as carrying single lambs subsequently gave birth to twins, and four ewes that had been identified as twin-bearing only gave birth to a single lamb; ewes were grouped for analysis based on lambing data as single- or twin-bearing. Two ewes in the control group in Experiment 1 gave birth to sets of triplets and were subsequently excluded from the analysis. In Experiment 2, 14 lambs were identified as single-born (eight supplemented, six control) but were also excluded from the analysis due to uncertainty as to whether a sibling had been born dead or a fetus aborted given that ewes had been scanned as twin-bearing. Data from the 15 ewes that gave birth to triplets in Experiment 2 (seven supplemented, eight control) and their associated lambs were also excluded.

All data were analysed using GenStat 14th edition (VSN International, UK). A significance level of $P < 0.05$ was used to identify differences that were statistically significant and $0.05 \leq P < 0.10$ are included to show differences approaching significance. Changes in FOO and differences in pasture nutritive values and mineral composition between treatments were analysed using linear mixed models with treatment, date and their interactions as fixed effects and plot/date as random effects. Differences between supplemented and unsupplemented treatments for ewe serum mineral concentrations, weight and BCS and lamb birthweights and growth rates were analysed using linear mixed models. For ewes, treatment, birth output (single or twin; Experiment 1 only) and time (measurement period corresponding to blood sampling or days grazing wheat in Experiment 1; weeks to lambing date or days grazing wheat in Experiment 2) and their interactions as fixed effects, and plot/ewe/time as random effects. Ewe BCS and weights were analysed using linear mixed models; treatment, ewe output (single/twin) and days grazing wheat and their interactions as fixed effects and plot/ewe/time as random effects. Birthweights were analysed using linear mixed models with sex as a covariate; treatment, birth status and their interactions as fixed effects, and plot/ewe as random effects. Lamb growth rates were analysed using linear mixed models with sex and final-rearing status at lamb marking tested as covariates; treatment, birth status, lamb age and their interactions as fixed effects and plot/ewe/lamb as random effects. Birthweights and growth rates of single- and twin-born lambs were then analysed separately for Experiment 1 in the same manner to determine separate standard errors for each group. Differences between treatments in lamb survival were analysed using a generalised linear mixed model with binomial distribution, with birth status (single or twin; Experiment 1 only), treatment and their interactions as fixed effects and plot/ewe as random effects. Lamb survival data was transformed on the logit scale for analysis and back-transformed for reporting of results.

Results

Forage availability and nutritive value

The available feed increased significantly ($P < 0.001$) from first to the second FOO measurement in both Experiment 1 and Experiment 2, and also increased from Day 39 to Day 60 in Experiment 2 (Table 1). The FOO did not differ significantly between control and supplemented treatments for any measurement date in either experiment.

Neutral detergent fibre (NDF), digestible organic matter in DM (DOMD), metabolisable energy (ME) and crude protein (CP) did not differ significantly between treatments on any sample date in either experiment. NDF was significantly higher on the second sampling date in both experiments, and ME and CP was significantly lower at the second sampling date in

Experiment 2 (Table 2). The DOMD of wheat forage was very high at the commencement of grazing in Experiment 2.

Table 1. Mean feed on offer (FOO, kg DM/ha) during Experiment 1 and Experiment 2

Date	Days from start	FOO
	Experiment 1	
15 June	–2	552
30 June	13	888
14 July	27	897
30 July	43	904
15 Aug.	59[A]	944
s.e.d.[B]	–	53
Experiment 2		
22 June	–1	1092
12 July	19	1505
1 Aug.	39	1359
22 Aug.	60	1887
s.e.d.[B]	–	128

[A] Final FOO in Experiment 1 was measured 3 days after conclusion of the experiment due to inclement weather.
[B] Average standard error of the difference.

The Ca, Mg, phosphorus (P), K and Na content of forage samples did not differ significantly between treatments within each sample date in either experiment, although K approached significance in Experiment 1 on the second sampling date (control > supplemented; $P = 0.083$) and Na approached significance on the second sampling date in Experiment 2 (supplemented > control; $P = 0.054$). The concentration of some minerals in wheat forage was significantly different between sample dates in the same experiment, particularly in Experiment 2 (Table 2). The K : Na and Ca : P ratios did not differ significantly between treatments in either experiment although the K : Na ratio approached significance on the second sampling date in Experiment 1 (control > supplemented; $P = 0.062$), and on the second sampling date in Experiment 2 (control > supplement; $P = 0.064$). The tetany index was significantly lower in control plots compared with supplemented plots at the commencement of Experiment 1 (5.7 vs 6.7; $P =$

Table 2. Mean nutritive values and mineral composition of samples taken at two sample dates during Experiment 1 and Experiment 2, and the composition of faba beans in Experiment 2.

	Units	Faba beans	18 June	13 July	s.e.d.	Significance[D]
Experiment 1(2010)						
DM	%		20.6	19.0	0.5	$P = 0.021$
ADF	% DM		18.3	23.9	2.6	$P = 0.089$
NDF	% DM		34.7	41.0	2.4	$P = 0.044$
DOMD	% DM		72.7	70.0	1.2	$P = 0.077$
ME[A]	MJ/kg		11.8	11.2	0.3	$P = 0.062$
CP	% DM		22.9	21.4	0.9	n.s.
Ca	% DM		0.28	0.26	0.01	n.s.
P	% DM		0.26	0.26	0.09	n.s.
K	% DM		4.8	5.3	0.2	$P = 0.057$
Mg	% DM		0.076	0.084	0.003	$P = 0.019$
Na	% DM		0.022	0.025	0.037	n.s.
Cl	% DM		0.61	1.08	0.05	$P < 0.001$
S	% DM		0.18	0.18	0.02	n.s.
NO_3	–		0.42	0.31	0.09	n.s.
K : Na	–		221	226	27	n.s.
Tetany index[B]	–		6.2	6.9	0.2	$P = 0.028$
Ca : P	–		1.07	1.01	0.05	n.s.
Experiment 2[C] (2011)			22 June	9 August		
DM	%	93.8	17.4	12.4	0.5	$P < 0.001$
ADF	% DM	9.0	19.2	30.0	1.0	$P < 0.001$
NDF	% DM	11.0	37.7	54.2	1.1	$P < 0.001$
DOMD	% DM	86.0	85.3	72.2	0.5	$P < 0.001$
ME	MJ/kg	12.5	14.3	11.7	0.1	$P < 0.001$
CP	% DM	23.7	29.6	24.2	0.6	$P < 0.001$
Ca	% DM	0.13	0.38	0.27	0.01	$P < 0.001$
P	% DM	0.35	0.44	0.40	0.01	$P = 0.005$
K	% DM	1.0	3.5	4.0	0.1	$P = 0.019$
Mg	% DM	0.130	0.096	0.105	0.003	$P = 0.020$
Na	% DM	0.002	0.007	0.009	0.000	$P = 0.004$
S	% DM	0.16	0.35	0.30	0.01	$P = 0.005$
NO_3	% DM	–	0.22	0.26	0.11	n.s.
K : Na	–	–	500	444	17	$P = 0.030$
Tetany index	–	–	3.4	4.6	0.2	$P < 0.001$
Ca : P	–	–	0.88	0.70	0.04	$P = 0.008$

[A] ME = 0.203 × DOMD – 3.001 (Packer et al. 2011).

[B] [(%K × 256)/(%Ca × 499 + % Mg × 823)], (Kempt and ‘t Hart 1957).

[C] No Cl concentration provided by laboratory in Experiment 2.

[D] Difference between sample dates for wheat samples; n.s. = not significant.

0.049) but there was no difference in the tetany index of forage between treatments in Experiment 2 on either sample date.

Ewes

Apparent consumption rate of mineral supplement was 24 g/head.day (equivalent to 5.5 g Mg, 3.6 g Ca and 1.9 g Na) in Experiment 1 and 16 g/head.day (equivalent to 3.7 g Mg, 2.4 g Ca and 1.3 g Na) in Experiment 2. Clinical cases of metabolic disease were not observed in any ewes during either experiment. Three ewes died during Experiment 1: one twin-bearing ewe (supplemented) prolapsed during lambing and was subsequently euthanased; the other two deaths were single-bearing ewes (unsupplemented) and died from infections. No ewes died during Experiment 2.

BCS did not differ significantly between treatments for ewes in Experiment 1 or Experiment 2. The mean BCS of single-bearing and twin-bearing ewes did not differ significantly at the commencement of grazing in Experiment 1; however, the condition score of single-bearing ewes was significantly higher ($P < 0.001$) compared with twin-bearing ewes from Day 21 of grazing wheat (Fig. 1). The mean BCS of ewes was significantly higher ($P < 0.001$) at the end of grazing wheat than at the commencement of grazing for single-bearing but not twin-bearing ewes in Experiment 1 (Fig. 1). While there was no difference between treatments in ewe BCS in Experiment 2, changes in BCS approached significance during the experiment ($P = 0.069$; Fig. 2).

The mean serum Ca concentration was significantly lower in the control group at the commencement of grazing (92.5 vs 97.0 mg/L; $P = 0.040$) but not for any other measurement period in Experiment 1. Magnesium, Na and P concentrations in serum did not differ significantly between treatments, and none of the serum mineral concentrations measured differed between single-bearing and twin-bearing ewes in any measurement period in Experiment 1 (Table 3). The Mg, Ca, Na and P concentrations in serum varied between measurement periods in Experiment 1 for single-bearing ewes ($P < 0.001$) and twin-bearing ewes ($P < 0.002$) (Table 3). Changes in serum Ca and Mg did not differ significantly with days grazing crop when

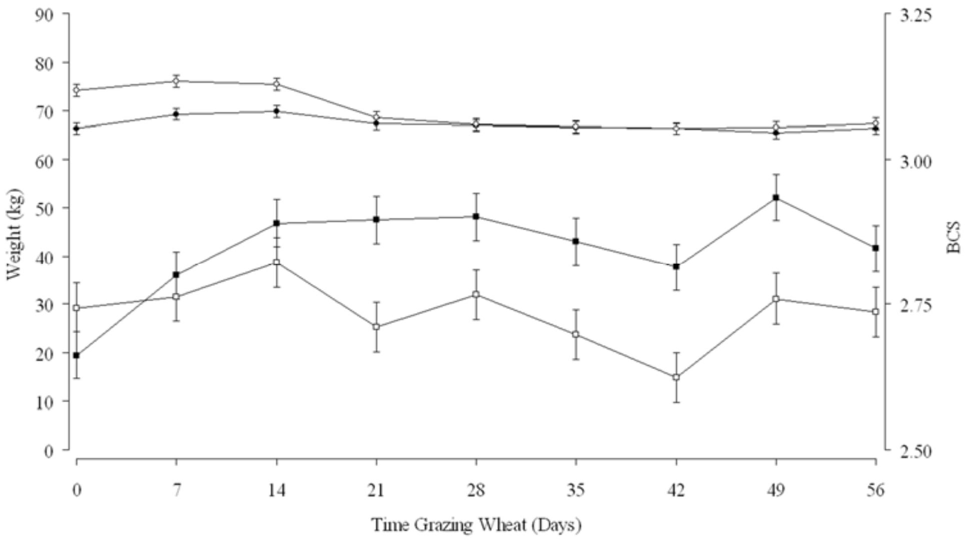

Fig. 1. Changes in liveweight and body condition score (BCS) of single- (● weight, ■ BCS) or twin-bearing (○ weight, □ BCS) ewes grazing wheat for 56 days in Experiment 1.

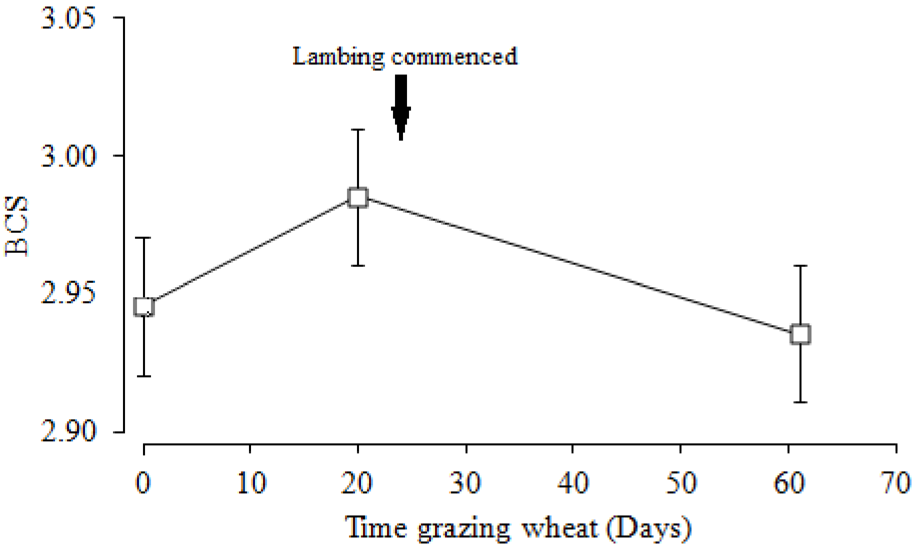

Fig. 2. Changes in body condition score of twin-bearing ewes grazing wheat for 61 days in Experiment 2.

the time to lambing date was included as a covariate, although the mean Ca concentration for the eight ewes in the control group on the final measurement date (83.8 mg/L; 28 ± 5 days post-partum) was the only mean value within the marginal band suggested by Suttle (2010). There were eight subclinical cases of hypocalcaemia detected based on Ca serum levels (five control, three supplemented) and all hypocalcaemic ewes were 23 or more days post-partum. Subclinical hypomagnesaemia, based on serum Mg levels, was detected in one single-bearing ewe in the control group after grazing wheat for 1 week, and in two single-bearing ewes (one control, one supplemented) during lactation.

Table 3. Mean serum mineral concentrations (mg/L) at the start, after grazing wheat for 7 days, in the first week of lactation and in the fourth week of lactation in Experiment 1

Values represent mean of subsample (five single-bearing or five twin-bearing ewes per plot) for measurement period

Period	Mg	Ca	Na	P
		Single		
Start	24.7	94.7[A]	3373	40.6
1 week grazing	24.5	103.1	3439	37.7
Start lactation	23.7	99.3	3398	43.3
Week 4 lactation	26.9	92.8	3370	46.8
Average s.e.d.	0.6	1.2	16	2.4
		Twin		
Start	24.7	93.3	3393.3	43.0
1 week grazing	25.7	102.0	3441.6	34.6
Start lactation	24.2	98.8	3384.1	43.4
Week 4 lactation	28.0	92.5	3384.1	46.3
Average s.e.d.	0.6	1.7	12.9	2.9

[A] Significant difference between treatments (supplemented>control; P = 0.040)

After 3 weeks of grazing in Experiment 2, the mean serum Ca concentration was significantly higher ($P < 0.001$) than the starting concentration, and remained at high levels in both treatment groups, with no effect from supplementation of ewes. Mean serum Mg concentrations did vary with the time grazing crop ($P < 0.001$), but there was no consistent trend and weeks to lambing date was not significant as a covariate ($P = 0.060$). Mean serum Mg, Na and P also did not differ significantly between treatments at the start or at any other measurement week in Experiment 2. Sodium ($P < 0.001$) and P ($P = 0.017$) levels in blood serum did vary significantly in relation to lambing date in Experiment 2, while changes in Ca ($P = 0.075$) and Mg ($P = 0.091$) did not (Table 4), and serum mineral concentrations did not differ significantly between treatments in relation to lambing date. Subclinical hypocalcaemia was detected in one ewe in the supplemented group, 2 weeks pre-partum. No ewes recorded serum Mg concentrations indicative of hypomagnesaemia in Experiment 2.

Table 4. Mean serum levels (mg/L) measured in relation to lambing date for twin-bearing ewes in Experiment 2 (five ewes per plot)
Average standard error of the difference (s.e.d.) is for weeks pre- or post-lambing

Period	No. ewes (*n*)	Mg	Ca	Na	P
Start		28.9	91.2	3414	36.1
Weeks pre-lambing					
–4	13	29.4	107.2	3366	49.0
–3	22	30.7	102.1	3384	43.1
–2	23	29.3	99.1	3423	46.4
–1	28	29.7	100.2	3425	45.8
Weeks post-lambing					
1	27	28.7	102.0	3349	38.5
2	29	28.2	103.0	3315	40.5
3	21	28.7	102.1	3308	45.4
4	13	30.5	103.9	3285	43.1
Average s.e.d.		1.0	2.4	15	3.1

Lamb survival, birthweights and growth

The survival rate of single-born lambs was significantly higher than twin-born lambs in Experiment 1 (89 vs 75%; $P < 0.001$) however survival rates did not differ significantly between treatment groups in either experiment (Table 5). Lamb birthweights and growth rates to lamb marking were significantly higher ($P < 0.001$) for single-born lambs compared with twin-born lambs in Experiment 1; however, there was no difference in birthweight between treatments in either birth status group (Table 5). The growth rate of twin-born lambs was significantly higher ($P = 0.002$) when ewes had access to supplement in Experiment 1, and final rearing status was not significant as a covariate; however, there was no difference between treatments in growth rate of single-born lambs in Experiment 1 (Table 5). Survival rates, birthweights and growth rates of twin-born lambs did not differ significantly between treatments in Experiment 2 (Table 5), and mothering ability did not differ significantly between treatment groups in Experiment 2 (both mean 2.3).

Table 5. Comparison between treatment groups of lamb birthweight, growth rates from birth to lamb marking and survival to lamb marking in Experiment 1 and Experiment 2

Age of lambs at lamb marking was 38 ± 10 days and 24 ± 8 days of age for Experiment 1 and 2, respectively.

Parameter	Units	Birth status	Treatment		s.e.d.	Significance
			control	supplemented		
			Experiment 1			
Number born		Single	116	107	–	–
Birthweight	kg	Single	6.1	5.9	0.6	n.s.
Growth rate	g/head.day	Single	323	327	3	n.s.
Survival	%	Single	88.8	88.8	–	n.s.
Number born		Twin	54	80	–	–
Birthweight	kg	Twin	4.9	4.9	0.1	n.s.
Growth rate	g/head.day	Twin	243	259	5	$P = 0.002$
Survival	%	Twin	72.7	77.5	–	n.s.
			Experiment 2			
Number born		Twin	114	116	–	–
Birthweight	kg	Twin	5.3	5.4	0.1	n.s.
Growth rate	g/head.day	Twin	304	310	6	n.s.
Survival	%	Twin	96.5	91.2	–	n.s.

Discussion

Ewes grazing dual-purpose wheat during the lambing period did not present clinical symptoms of metabolic diseases such as hypocalcaemia and hypomagnesaemia despite Ca, Mg and Na levels in wheat forage being below ewe requirements, and ewe serum levels of Ca and Mg were maintained within the normal range in most ewes sampled. Ewes grazing wheat forage readily consumed a loose-lick mineral supplement that contained these minerals when it was available; however, the benefits of providing mineral supplements to prevent mineral deficiencies are not clear from these experiments. A complication in identifying the response to mineral supplementation is variability between individual animals in their consumption of mineral supplements, with apparent intakes based on group in this study. Notwithstanding this, an increase in the growth rate of twin-born lambs was detected when Merino ewes grazing dual-purpose wheat were provided with a mineral supplement in Experiment 1.

The Ca concentrations in wheat forage were comparable to other recent findings, albeit at the lower end of the range, and were below the requirements for late-pregnant ewes (CSIRO 2007). Ewes are most susceptible to hypocalcaemia during late pregnancy (Treacher and Caja 2002) although it may occur during lactation (Blumer *et al*. 1939; Watt 2006), and low dietary Ca may precipitate hypocalcaemia in late-pregnant ewes (Larsen *et al*. 1986; Elias and Shainkin-Ketenbaum 1990); however, no clinical cases of hypocalcaemia were observed in either experiment.

Ewes may be in negative Ca balance during early lactation (Braithwaite *et al.* 1969), and a decline in serum Ca was observed during the first 4 weeks of lactation in Experiment 1. In contrast, the lowest mean serum Ca was 8 – 14 days pre-partum in Experiment 2 with levels increasing again in lactation, a pattern similar to the observations of Sansom *et al.* (1982), although in their study the lowest Ca levels were observed 4 weeks pre-partum. The high serum Ca status of ewes in Experiment 2 throughout lactation may be due to the younger ewe age group and mineral supplementation regime of ewes during the dry period assisting repletion of skeletal reserves (Sansom *et al.* 1982; Sargison 2009).

The Mg content of wheat forage was lower in Experiment 1 than observed in other recent studies, and below the requirements of late-pregnant and lactating ewes in both experiments (CSIRO 2007). Sheep are most susceptible to hypomagnesaemia during the first 4 – 6 weeks after lambing (Treacher and Caja 2002), and the mineral profile of wheat forage in this study suggested that ewes grazing dual-purpose wheat may have been at increased risk of hypomagneasaemia. When the tetany index exceeds 2.2 precautions against grass tetany may be necessary (CSIRO 2007), and the tetany index for wheat grazed by ewes in the present study exceeded this threshold on all dates measured. Despite this only three ewes were hypomagnesaemic, and no clinical cases were observed in either experiment. The tetany index, which was developed from observations in cattle in the Netherlands, may therefore not provide a relevant indication of the hypomagnesaemia risk for sheep grazing pastures.

The K : Na ratio was much higher in Experiment 2 compared with Experiment 1, and this was due to the much lower Na content of forage in Experiment 2, as K levels were actually higher in Experiment 1. Forages with K concentrations as low as 2 – 3% can have a large negative effect on Mg absorption and may therefore be tetany prone (Greene *et al.* 1983), but the effect of high K can be mitigated by increasing Na intake (Khorasani and Armstrong 1990). Therefore, sheep grazing dual-purpose wheat may be at greater risk of developing hypomagnesaemia due to the high K : Na content of wheat compared with other pasture species, although we did not observe any clinical cases in our study.

The mineral composition of wheat forage implies the potential for hypocalcaemia and hypomagnesaemia in ewes grazing dual-purpose wheat. While no clinical cases of metabolic disease were observed in our study, it would seem prudent to provide a mineral supplement to ewes grazing wheat as a preventative measure (McGrath *et al.* 2013). For producers undertaking this practice an awareness of other pre-disposing factors is important. Blumer *et al.* (1939) noted that hypocalcaemia often occurred following the removal of ewes from lush pastures and was precipitated by droving; therefore, this may be a risk period for ewes grazing wheat crops. Maintaining adequate BCS of ewes entering the lambing period may be important to prevent high ewe losses when grazing wheat (McGrath *et al*. 2013). The BCS at the commencement of Experiment 1 was similar to the average condition score in flocks where higher than normal ewe mortality rates associated with grazing wheats were reported by producers in southern NSW (McGrath *et al*. 2013). The comparatively low ewe mortality rate observed in our study may relate to a smaller range in BCS, with no very light animals included in these experiments.

The increased growth rate to lamb marking of twin-born lambs in the supplemented group in Experiment 1 is an important production outcome. Ewes with multiple lambs generally produce more milk than single-bearing ewes and have increased requirements for minerals such as Ca (Treacher and Caja 2002), and this may explain why superior growth rates were detected only in twin-born lambs where dams were provided with access to a supplement. Low Na or Mg intakes by ruminants can cause inappetance (Suttle 2010), while milk production has been shown to increase when dairy cows are supplemented with Na or Mg when the diet is deficient in these minerals (Joyce and Brunswick 1975; CSIRO 2007). Therefore, the increased lamb growth rates observed in Experiment 1 could be due to higher milk production when twin-bearing ewes were fed a mineral supplement. The reason for the absence of improvement in growth rate of twin-born lambs as a result of providing a mineral supplement in Experiment 2 is unclear. The very high growth rates observed in Experiment 2, which were similar to those observed for single-born lambs in Experiment 1, suggests that these lambs may have been growing at a maximum rate, and the forage mineral deficiencies were not marked. The Ca, P and Mg concentrations in wheat forage were higher in Experiment 2 than Experiment 1. The absence of an effect on lamb growth rates from supplementation of ewes in Experiment 2 may also relate to the higher BCS of ewes and higher digestibility, CP and availability of forage (Penning *et al*. 1991; Morris *et al*. 1994; Treacher and Caja 2002).

Industry recommendations are for a minimum pasture availability of 1000 kg green DM/ha (single-bearing) and 1200 kg green DM/ha (twin-bearing) to meet the requirements of late-pregnant ewes (Hatcher 2006). Available feed was below these levels at all measurement dates in Experiment 1 and at the commencement of grazing in Experiment 2; however, the health and production of ewes did not appear to be adversely affected, suggesting separate recommendations may be required for ewes grazing wheat. The large increase in FOO observed during Experiment 2 suggests that a higher stocking rate may also be possible if the starting pasture mass is higher; however this will also depend on prevailing seasonal conditions.

Conclusion

Wheat forage may be below the reported requirements of ewes during late-pregnancy and lactation for Ca and Mg; despite this, ewes grazing on dual-purpose wheat in these physiological states did not develop clinical hypocalcaemia or hypomagnesaemia. Providing a mineral supplement to ewes grazing wheat did not alter blood mineral status of ewes but did increase the growth rate of twin-born suckling lambs in one experiment.

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