The performance of replacement, spring calving dairy heifers out-wintered on deferred grazing, kale or fodder beet, and the influence of a trace mineral bolus

Research Partnership: Grasslands, Forage and Soil

Work Package 4: Out-wintering as an alternative for replacement heifers reared for low or high input milk production systems

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1.1 Farmer recommendations

- There is more variation in heifer performance between individual farms than due to the out-wintered forage. Decisions on the most appropriate forage should therefore be made on soil type and crop yield.

- Supplementing with a mineral bolus has a marginal effect on body condition prior to calving, and increases milk fat content in early lactation, especially in herds grazing kale.

- There is no subsequent effect of out-wintering forage type or provision of a mineral bolus during the out-wintering period on the health or reproductive performance of first lactation cows.

- If an appropriate choice of soil type is made, there is little difference in soil conditions on farms out-wintering on grass, kale or fodder beet, with an increase in soil compaction post-grazing on all three systems.

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1.2 Executive summary

Performance pre- and post-calving of heifers out-wintered in commercial herds was investigated on nine spring calving, grazing based, crossbred dairy farms that were out-wintering pregnant heifers due to calve at 24 months of age from February 2013. Three of the farms were grazing deferred grass (G), three kale (K) and three fodder beet (F). Feeding protocol, quantity of crop offered, and supplementary feed followed the commercial practice on each farm. On each farm, a sub-set of 40 Holstein-Friesian x Jersey heifers were randomly allocated to one of two treatments; either a long acting trace mineral bolus (B+; CoSelCure, Telsol Ltd, Leeds, UK), or no bolus (B-). The study heifers were managed within the larger group of non-study heifers. The farms were visited over a 12 wk period on three occasions (early November 2012), middle (prior to Christmas 2012), and end of the wintering period (end Jan/beginning February 2013) and performance and crop yield recorded. Details of calving, health and fertility were recorded on each farm, and each was visited at approximately wk 10 and 19 post mean calving date, and milk performance recorded. A summary of performance is provided in Table S1.

Table S1. Performance of pregnant heifers out-wintered on grass (G), kale (K) or fodder beet (F), and either did not receive (B-) or received (B+) a trace mineral bolus.

	G	K	F	s.e.d.	*P*-value	B-	B+	s.e.d.	*P*-value
Rearing period[1]									
LWG[2] kg/d	0.18	0.42	0.15	0.234	0.492	0.25	0.25	0.024	0.968
BCS[3], wk 12	2.49	2.48	2.38	0.117	0.636	2.44	2.47	0.016	**0.035**
Plasma minerals wk 12									
Cu,mmol/L	12.0	13.3	13.5	2.09	0.753	11.3	14.6	0.57	**<0.001**
Se, µmol/L	0.67	0.63	0.73	0.146	0.820	0.50	0.86	0.03	**<0.001**
Lactation (wk 10)									
Milk yield, kg	18.2	19.2	16.4	1.85	0.390	17.8	18.1	0.35	0.394
FCM[4], kg	18.6	19.5	17.1	1.98	0.526	18.1	18.7	0.39	0.087
Fat, g/kg	41.7	40.2	43	0.22	0.549	40.7	42.6	0.71	**0.009**
BCS[3]	2.13	2.02	2.03	0.075	0.332	2.07	2.05	0.025	0.611
SCC[5], log_{10}	1.74	1.76	1.81	0.086	0.605	1.78	1.76	0.043	0.593
Reproduction									
% cycling at start	76	82	53	-	>0.1	75	69	-	0.225
% returned to 1st service	57	57	52	-	>0.1	54	57	-	0.572
% conceived	88	86	95	-	**<0.05**	90	91	-	0.748

[1]Wk 0-12 = 1 Nov 2012 to end Jan 2013; [2]live weight gain; [3]body condition score; [4]Fat corrected milk yield; [5]somatic cell count

Results:

- Growth performance was very variable between and within farms during the out-wintering period.
- There was no effect of forage source or provision of a mineral bolus on animal performance, except body condition prior to calving which was slightly higher in animals receiving a bolus
- Provision of a trace mineral bolus increased blood concentrations of the minerals supplied in the bolus
- There was no effect of out-wintered forage source on milk performance, but a bolus increased milk fat content, and tended to increase fat corrected milk yield in early lactation, especially in herds that had grazed kale
- There was no effect of treatment on health or reproductive performance, except for the overall percentage conceived, which was higher in farms that had fed fodder beet during the rearing period

2. Background

With the drive towards increasing dairy herd size as a means of cost effective milk production (DairyCo, 2014), comes increasing pressure on buildings to accommodate the cattle. Options to facilitate increasing numbers of cattle in the milk herd in both low input and high input dairy systems include capital investment in the construction of dedicated additional heifer replacement buildings, woodchip pads (McCarrick and Drennan, 1972; Boyle et al., 2008) or purchasing down-calving replacement heifers. Another alternative to permit dairy herd expansion without the need for major capital investment is to out-winter replacement heifers. These low capital systems have the potential to decrease rearing costs by reducing housing, bedding and feed costs. Replacement heifers can be out-wintered as peri-pubertal (during their first winter) and in-calf heifers, to calve for the first time after their second winter outside.

Previous studies (Redbo et al., 2001; Morgan et al., 2009; O'Driscoll et al., 2010) suggest that dairy heifers adapt well to cold climatic conditions provided that they are kept on free draining soils with shelter available to protect the animals from the wind, and a dry lying area. If ambient temperatures drop below the lower critical temperature of the cattle they have been shown to adapt their behaviour and location to reduce energy expenditure (Redbo et al., 2001; Morgan et al., 2009). Some studies have shown a reduction in the growth of heifers through the winter period, particularly with autumn-born heifers (Ridler and Broster 1968), although others have shown no overall effect (Redbo et al., 1996; Marsh et al., 2009). Performance on farm appears to be related to a number of variables including feed source and allowance, health, shelter and lying conditions. Evidence also suggests that there will be little effect on subsequent lactation performance in heifers reared to calve at 30 to 35 months of age (Ridler and Broster 1968) although less information is available on modern genotypes calved at 24 months.

Through the winter months, grass growth and quality is insufficient to support the target levels of animal performance (French et al., 2009; Morgan et al., 2009). However, research studies (Marsh et al., 2009) and reported commercial practice (Atkins et al., 2014; Farmers Guardian, 2009) suggest that these targets can be met by feeding high energy forage brassicas (e.g. swift hybrid brassica, stubble turnips or kale) or fodder beet, provided the animals have access to baled grass silage. Strip-grazed swift has been fed to support growth rates of 0.7 kg per head per day in Friesian cross in-calf heifers reared to calve in the spring at 500kg (Farmers Guardian, 2009) and similar performance was achieved in Holstein heifers fed stubble turnips (Marsh et al, 2009).These low input systems are typically used to rear heifers (Atkins et al., 2014) or maintain dry in-calf cows for spring calving grass-based lower input systems (French et al., 2009).

The advantages of dedicated out-wintering forages such as kale and fodder beet may be offset by the presence of anti-nutritional factors. For example, kale has a number of anti-nutritional factors including s-methyl cysteine sulphoxide, goitrins and thiocyanates (McDonald et al., 2011). Fodder beet is high in soluble carbohydrates which are associated with acidosis and contain oxylates in the leaves which can bind calcium and affect kidney metabolism (McDonald et al., 2011). To reduce the potential negative effects many farmers supplement with big bale silage to provide on average 35% of the DM intake (Atkins et al., 2014). Some farmers also supplement with minerals, with trace element boluses being the most popular (Atkins et al. 2014). A recent survey has indicated that for housed, winter fed dairy cows that minerals are generally supplied well in excess (Sinclair and Atkins 2014), although the benefits of supplementation on animal performance and subsequent fertility in low input, out-wintered systems is unclear.

2.1 Objectives

1. To determine the growth and lactation performance, health and welfare of 18-24 month old, in-calf crossbred dairy heifers out-wintered on deferred grazing, kale or fodder beet in commercial herds.

2. To determine the effect of a trace element mineral bolus on winter animal performance, health and blood mineral status, and subsequent first lactation milk production and fertility

3. To monitor the effect of rearing system on winter soil conditions

3. Materials and methods

3.1 Farms

In the summer of 2012, 9 spring calving, grassland based dairy farms that were due to out-winter heifers in 2012/2013 were recruited for the study. The suitability of the farms selected was based on their forage type, calving dates and pattern, breed, expected production, frequency of milking, location, experience of out-wintering heifers, and willingness and ability to be part of the study (i.e. that they recorded mating, record health, had facilities for milk recording etc.). Location of the study farms is provided in Figure 1.

Figure 1. Location and basal forage on the 9 commercial farms outwintering replacement heifers on deferred grazing (G), kale (K) or fodder beet (F).

3.2 Forage

Based on the out-wintering survey conducted in 2012 (Akins et al., 2014), the most widely used forages grazed by heifers more than one year old on commercial dairy units were deferred grazing (55%), kale (42%) and fodder beet (32%). Three farms were therefore selected which were due to graze kale, three fodder beet, and three deferred grazing. Feeding protocol, quantity of crop, type and quantity of supplementary feeds was as per the commercial practice on each farm. Post calving, all animals were rotationally grazed on grass with supplementary feed in accordance with each farms normal practice.

3.3 Animals

On each of the 9 farms, a sub-set of 40 Holstein-Friesian x Jersey heifers were selected for the study. The heifers were due to calve at approximately 24 months old from February 2013. The animals were kept together throughout the winter but were managed within larger groups including non-trial heifers. Coloured tail tapes were used to identify the animals. In total, 360 heifers were used.

3.4 Mineral treatment

Within each farm the 40 heifers were paired according to live weight and breed and randomly allocated to one of two mineral treatments. At the start of the study, 20 heifers on each farm received a long acting (6 months for animals at pasture) trace mineral bolus (CoSelCure, Telsol ltd, Leeds) according to the manufacturers recommendations. Two boluses per animal were administered, each bolus containing copper 13.4g; cobalt 0.5g; selenium: 0.15g (as sodium selenite); Iodine 1.0g (as calcium iodate). The remaining 20 animals in the study group did not receive a bolus, and no other forms of mineral supplementation were made available during the out-wintering period.

3.5 Experimental routine

The farms were visited on three occasions during the out-wintering period – beginning (early November 2012), middle (prior to Christmas 2012), and end of the out-wintering period (end Jan/beginning February 2013). On each occasion, the heifers were weighed at approximately 10am using electronic weigh cells (Trutest, Auckland, New Zealand), body condition scored (Mulvany, 1977), scored for cleanliness (Boyle et al, 2008) and mobility scored (Chipinal et al, 2009). Blood samples were also collected via the coccygeal vein for subsequent analysis. On visit 1 and 3, a hair length sample was taken as described by Boyle et al (2008).

Crop yield was measured on each of the three visit dates. Fresh weight of kale was measured by collecting 6 random 1m^2 quadrats cut to ground level. Fodder beet yield was assessed by pulling beet from 6 random quadrats, each 1m long x 2 rows wide, whereas grass yield was assessed using a rising plate meter with the equation $kg\ DM/Ha = x125 + 640$, and measuring 10 random 0.1 m^2 quadrats, cut to ground level. Where possible, residual herbage mass was assessed in a similar fashion to estimate crop utilization. Samples of supplementary feed offered to the animals were also taken. Dry matter content was determined by drying subsamples at 105°C for 24 hours.

At each visit, eight soil cores (8cm diameter x 10cm) were taken from the pre grazing side of the fence and eight from the post grazing side. Soil cores were dried at 105°C until a constant weight. Dry bulk density was determined using the formula

$$Dry\ bulk\ density = \frac{M_{wet} - M_{dry}}{V}$$

soil moisture by

$$Soil\ moisture\ (g/g) = \frac{M_{wet} - M_{dry}}{M_{wet}}$$

and

$$Soil\ moisture\ (vol/vol) = \frac{M_{wet} - M_{dry}}{V}$$

Where M_{wet} is the mass of wet soil, M_{dry} is the mass of dry soil, and V the volume of the core.

Soil surface poaching was assessed at each visit by eight roller chain measurements from the pre grazing side of the field (randomly taken over the next weeks grazing allocation), and eight roller chain measurements from the post grazing side of the field (randomly taken from the past weeks grazing allocation). A roller chain measurement consisted of a standard bicycle chain lain across the soil to follow the undulations on the surface. The length of extra chain needed (cm) to cover a metre rule was recorded.

During the out-wintering period, the farms recorded information for calculating amount of crop offered (number of animals, size of fields, date on and off fields). From calving, the farms recorded calving date, calving ease score, incidence of retained placenta (longer than 12 hr), lameness, mastitis and metritis, pre-mating oestrus checks, dates of insemination and pregnancy diagnosis outcome following their mating period. The calving ease score was chosen to ensure consistency between different observers and was as follows:

1. No assistance/calved unaided,
2. Farmer assistance – normal presentation,
3. Farmer assistance – mal presentation,
4. Vet assistance.

Milk yield, milk fat and protein content and somatic cell count were monitored on each farm approximately 10 weeks and 19 weeks post the mid-point of calving. Body condition score and mobility were also recorded at these times.

3.6 Chemical analysis

The forage samples were analysed for dry matter, crude protein, water soluble carbohydrate and neutral detergent fibre by wet chemistry, and for grass silage the metabolisable energy (ME) content was predicted from the MADF content. In addition, forages were analysed for Cu, Se, Co, Fe, Mn, Mo, Zn, Ca, Mg, P, K and Na using the DigiPREP digestion system (Qmx Laboratories, Essex, UK) and analysis by ICP-MS (Thermo Fisher Scientific Inc., Hemel Hempstead, UK) as described by Sinclair and Atkins (2014).

Whole blood samples samples were analysed for haematology using a Vet Animal Blood Counter (Woodley Equipment Company Ltd., Bolton, UK). Blood plasma samples were analysed for Cu, Fe, Mn, Mo, Zn, Se, Co by inductively coupled plasma-mass spectrometry (ICP-MS; Thermo Fisher Scientific Inc., Hemel Hempstead, UK) as decribed by Cope et al., (2009). Blood samples were analysed for β-hydroxybutyrate and urea (Randox Laboratories, County Antrim, UK; kit catalogue no. RB 1007 and UR221, respectively) using a Cobas Miras Plus autoanalyser (ABX Diagnostics, Bedfordshire, UK).

3.7 Statistical analysis

Data were analysed using Genstat version 15. Continuous variables were analysed by ANOVA as a 3 x 2 factorial design with main effects of forage source, bolus addition and their interaction. Initial values were used as covariates where appropriate and days in milk was included as a covariate in the analysis of milk production variables. Health and fertility data were analysed by logisitic regression including forage source and bolus addition in the fixed model and farm as a random term. The majority of heifers calved with a calving ease score of either 1 (no assistance) or 2 (farmer assistance – normal presentation), therefore, calving ease data were reclassified into two categories for analysis by logistic regression. Similarly, mobility score was reclassified as either not lame (scores 1 and 2) and lame (scores 3,4 and 5) for logistic regression analysis.

4. Results

4.1. Crop yield and chemical composition

Crop yield (kg DM/ha) was highest (P<0.001) on farms that were grazing fodder beet, with a mean yield that was 2.3 times that of farms grazing kale (Table 1). The lowest yield of 3.1 t DM/Ha was recorded on farms that were grazing grass, 5.4 and 16.8 t DM/ha less than that recorded on the farms grazing kale or fodder beet, respectively. The estimate of herbage mass by rising plate meter was 2.9 t DM/Ha using the standard UK equation, a slightly lower value than that obtained by the quadrat cut method. The DM of the three forages were similar, with a mean value of 151 g/kg DM. In contrast, crude protein content was higher (P=0.05) in kale than fodder beet, with grass having an intermediate value. Water soluble carbohydrate was highest (P<0.001) in the fodder beet and lowest in the grass, whereas NDF was lowest (P<0.001) in the fodder beet and highest in the grass, with kale having an intermediate value. With respect to mineral content, kale had the highest content of Ca (P<0.001) and S (P<0.01), but the lowest concentration of Co (P<0.01), and tended (P<0.1) to have the lowest concentration of Zn. Grass had the highest (P<0.001) concentration of Mn (P<0.001) and Cu (P<0.01) of all three forages, whereas fodder beet was particularly high in Na and low in Ca and Mo. Selenium levels tended (P<0.1) to be higher in grass than kale or fodder beet.

Table 1. Crop yield and chemical composition of grass and kale and fodder beet crops fed to out-winter dairy heifers on 9 commercial farms.

	G	K	F	s.e.d.	*P*-value
Yield (kg DM/ha)	3.1	8.5	19.9	1.61	<0.001
Dry matter (g/kg)	160	134	158	13.0	0.157
Crude protein (g/kg DM)	128	164	87	24.5	0.053
ME (MJ/kg DM)	10.9	-	-	-	-
Water soluble carbohydrate (g/kg DM)	100	257	494	37.6	<0.001
Neutral detergent fibre (g/kg DM)	521	302	179	24.4	<0.001
Minerals					
Na (g/kg DM)	0.7	1.2	4.8	0.91	0.008
Mg (g/kg DM)	1.6	1.7	2.6	0.30	0.027
P (g/kg DM)	2.8	3.3	2.1	0.49	0.123
S (g/kg DM)	1.9	5.8	0.5	1.18	0.010
K (g/kg DM)	16.8	31.8	24.9	5.71	0.101
Ca (g/kg DM)	7.5	15.2	3.2	0.71	<0.001
Fe (g/kg DM)	3.0	0.1	1.2	1.05	0.090
Mn (mg/kg DM)	213.0	15.1	57.2	20.33	<0.001
Co (mg/kg DM)	1.1	0.1	0.3	0.20	0.007
Cu (mg/kg DM)	7.7	1.6	4.9	0.95	0.002
Zn (mg/kg DM)	38.3	15.4	37.0	9.13	0.080
Se (mg/kg DM)	0.2	0.1	0.1	0.05	0.084
Mo (mg/kg DM)	1.3	1.0	0.1	0.20	0.003

4.2. Chemical composition of the supplementary forage

On all 9 farms, big bale grass silage was the supplementary forage source used, and the chemical and mineral analysis are presented in Table 2. There were no differences (P>0.05) in the chemical composition between farms that out-wintered on grass, kale or fodder beet with mean DM, crude protein, ME, water soluble carbohydrate and NDF of 432 g/kg, 112g/kg DM, 9.7 MJ/kg DM, 42 g/kg DM and 594 g/kg DM respectively. Similarly, there were no differences (P>0.05) between treatments in grass silage mineral concentration.

Table 2. Chemical composition of supplementary feed to dairy heifers out-wintered on grass, kale or fodder beet crops on 9 commercial farms.

	G	K	F	s.e.d.	*P*-value
Dry matter (g/kg)	388	368	541	150.6	0.496
Crude protein (g/kg DM)	114	121	101	17.2	0.564
ME (MJ/kg DM)	9.8	10.0	9.3	0.43	0.306
Water soluble carbohydrate (g/kg DM)	19	29	78	33.3	0.243
Neutral detergent fibre (g/kg DM)	601	554	628	38.6	0.233
Minerals					
Na (g/kg DM)	2.5	1.3	2.9	1.56	0.600
Mg (g/kg DM)	1.8	2.0	2.0	0.48	0.923
P (g/kg DM)	2.8	2.9	2.9	0.53	0.954
S (g/kg DM)	2.2	2.3	3.3	1.82	0.823
K (g/kg DM)	24.0	28.0	20.6	4.99	0.396
Ca (g/kg DM)	5.9	5.6	3.3	1.38	0.202
Fe (g/kg DM)	0.8	0.4	0.4	0.33	0.361
Mn (mg/kg DM)	209.0	86.7	259.7	98.07	0.270
Co (mg/kg DM)	0.3	0.1	0.1	0.09	0.167
Cu (mg/kg DM)	3.5	3.6	4.0	1.08	0.911
Zn (mg/kg DM)	28.2	20.2	22.6	7.07	0.549
Se (mg/kg DM)	0.2	0.1	0.1	0.13	0.657
Mo (mg/kg DM)	1.1	1.3	0.7	0.31	0.255

4.3. Forage and supplement intake

The amount of forage crop offered was greater on farms that were grazing kale, although the difference was not significant (Table 3). In contrast, farms that grazed grass offered more than twice the amount of grass silage than those grazing kale or fodder beet ($P<0.001$). Additionally, the amount of grass silage offered to heifers increased ($P<0.05$) on farms grazing grass between November and December, but not on any of the other treatments. Over the whole of the study period there was no difference ($P>0.05$) in the total daily DM allowance between farms grazing different crops. Grass utilisation averaged 41% with mean post grazing herbage mass 2008 kg DM/Ha, although post grazing residual DM could be in excess of 3000 kg DM/Ha on one farm (that intended to graze the field the following season), and was not measurable on another (due to heavy poaching and intention to plough the fields post-grazing). When estimated using the rising plate meter, post grazing herbage mass was 1480 kg DM/Ha for farms using grass, more than 500 kg DM/Ha less than measured using the quadrat cut method. Utilisation of kale and fodder beet was estimated to be 89 and 93%, respectively.

Table 3. Estimated feed offered to replacement heifers reared outside between November 2012 and January 2013 on grass (G), kale (K) or fodder beet (F)

	G	K	F	s.e.d.	*P*-value
Crop offered (kg DM/head/day)	4.7	10.2	4.8	2.78	0.173
Silage offered (kg DM/head/day)	10.2	3.6	4.1	0.78	<0.001
Total offered (kg DM/head/day)	14.9	13.8	9.0	3.00	0.207

4.3. Animal performance

Mean live weight at the beginning of the study, after 6 weeks and 12 weeks, or live weight gain did not differ ($P>0.05$) between animals out-wintered on grass, kale or fodder beet (Table 4). Similarly, there was no effect ($P>0.05$) of a mineral bolus on live weight. However, there was an interaction between forage source and time ($P<0.001$), with live weight of heifers grazing kale or grass increasing between each visit, while heifers grazing fodder beet had no change in live weight between wk 6 and wk 12. There was also a decrease in daily live weight gain ($P<0.001$) after wk 6 for cattle grazing kale or fodder beet, but not for those grazing grass. There was no effect ($P>0.05$) of forage source or the provision of a bolus on body condition or body condition score change, except for body condition score at week 12 of the study, which was higher ($P<0.05$) in heifers that received a mineral bolus compared to those that did not. The final sampling day on each farm (wk 12) fell a mean of 26 days before the mid-point of calving.

Table 4. Growth performance and body condition of replacement heifers reared outside between November 2012 and January 2013 on grass (G), kale (K) or fodder beet (F), and either did not receive (B-) or received (B+) a mineral bolus.

	G	K	F	s.e.d.	*P*-value	B-	B+	s.e.d.	*P*-value
Live weight, kg									
wk 0	429	400	384	20.6	0.166	404	405	1.1	0.817
wk 6	434	426	393	27.2	0.345	417	418	1.4	0.625
wk 12	445	432	394	28.7	0.255	424	424	2.1	0.863
Live weight gain, kg/d									
0-6 wk	0.11	0.57	0.34	0.464	0.631	0.34	0.34	0.034	0.961
6-12 wk	0.23	0.15	0.01	0.250	0.686	0.13	0.13	0.040	0.966
0-12 wk	0.18	0.42	0.15	0.234	0.492	0.25	0.25	0.024	0.968
Body condition									
wk 0	2.73	2.72	2.55	0.152	0.467	2.67	2.67	0.019	1.000
wk 6	2.64	2.59	2.56	0.088	0.636	2.60	2.59	0.016	0.801
wk 12	2.49	2.48	2.38	0.117	0.636	2.44	2.47	0.016	0.035
Weekly body condition change									
0-6 wk	-0.02	-0.02	0.01	0.027	0.471	-0.01	-0.01	0.005	0.417
6-12 wk	-0.03	-0.03	-0.04	0.010	0.608	-0.03	-0.03	0.007	0.476
0-12 wk	-0.03	-0.03	-0.02	0.009	0.690	-0.02	-0.02	0.004	0.939

4.4. Dirt score and hair length

There was no effect ($P>0.05$) of forage source or the provision of a mineral bolus on average dirt score (Table 5). All treatment groups increased in dirt score between wk 0 and 12 of the study, and there was an interaction between forage source and time ($P<0.001$), with cattle out-wintered on kale or fodder beet having consecutively higher dirt scores at each visit, whereas those grazing grass remained unchanged between wks 6 and 12. There was no effect of treatment on hair length, with mean length increasing from 21.1 mm at the beginning of November 2012 to 25.5 mm by the end of January 2013.

Table 5. Body dirt score and hair length of pregnant heifers reared outside between November 2012 and January 2013 on grass (G), kale (K) or fodder beet (F), and either did not receive (B-) or received (B+) a mineral bolus.

	G	K	F	s.e.d.	*P*-value	B-	B+	s.e.d.	*P*-value
Average dirt score									
wk 0	1.91	1.61	2.13	0.297	0.284	1.89	1.88	0.035	0.831
wk 6	2.88	2.38	2.70	0.306	0.332	2.63	2.67	0.032	0.233
wk 12	2.86	2.54	2.82	0.224	0.358	2.75	2.73	0.044	0.726
Hair length, mm									
wk 0	21.3	20.3	21.8	0.65	0.134	20.9	21.3	0.49	0.435
wk 12	26.3	24.7	25.4	1.56	0.627	25.1	25.8	0.47	0.135

4.5. Plasma mineral concentration

There was no difference (P>0.05) in the mean concentration of any of the minerals measured at the beginning of the study in heifers grazing grass, kale or fodder beet, except plasma Se which was higher (P=0.038) in animals about to receive a bolus (B+, 0.46 µmol/L) than those not receiving a bolus (B-, 0.42 µmol/L; Table 6). There was also no effect of basal forage or the provision of a trace mineral bolus on plasma concentrations of Mn or Fe at wks 6 or 12 of the study. Mean plasma Zn concentrations decreased between wk 0 and wk 6, and wk 6 and wk 12 (P<0.001). There was also an interaction (P<0.001) between time and forage source on plasma Mo concentrations, which increased between week 0 and week 6 in cattle out-wintered on grass, and decreased between wk 0 and wk 12 for cattle out-wintered on kale.

Plasma Cu concentrations were similar in heifers out-wintered on grass, kale or fodder beet, and remained within the accepted range at both wk 6 and 12 of the study period. However, there was an effect of the addition of a mineral bolus on plasma Cu concentrations, with animals receiving a bolus having higher (P<0.001) concentrations at wks 6 and 12, although the unsupplemented group were still within the accepted range. Similarly, plasma Se concentrations in heifers that received the bolus were approximately double the values of those that did not receive the bolus. There was an interaction (P<0.001) between time and bolus, with plasma Se levels increasing between wk 0 and wk 6 but decreasing between wk 6 and wk 12 for cattle receiving a bolus.

Finally, plasma Co concentrations were 1.8 fold higher at wk 6 and wk 12 of the study in heifers receiving a bolus. There was also an interaction (P<0.001) between time and bolus on plasma Co levels, which increased between wk 0 and wk 6 but decreased between wk 6 and wk 12 for cattle receiving a bolus.

Table 3. Plasma mineral concentrations in pregnant heifers reared outside between November 2012 and January 2013 on grass (G), kale (K) or fodder beet (F), and either did not receive (B-) or received (B+) a mineral bolus.

	G	K	F	s.e.d.	*P*-value	B-	B+	s.e.d.	P-value	Normal Range
Copper, µmol/L										
wk 0	14.4	10.6	13.8	3.96	0.609	12.5	13.4	0.65	0.191	
wk 6	14.0	13.6	15.0	3.62	0.934	12.2	16.2	0.50	<0.001	10 - 20
wk 12	12.0	13.3	13.5	2.09	0.753	11.3	14.6	0.57	<0.001	
Zinc, µmol/L										
wk 0	12.3	14.6	12.7	5.11	0.896	12.8	13.5	0.49	0.153	
wk 6	11.0	11.2	11.9	5.20	0.981	11.4	11.3	0.30	0.917	10 - 18.5
wk 12	10.7	10.4	11.0	4.58	0.991	10.8	10.6	0.35	0.709	
Molybdenum, µmol/L										
wk 0	0.43	0.37	0.44	0.264	0.955	0.42	0.41	0.027	0.613	
wk 6	0.71	0.31	0.45	0.332	0.516	0.49	0.49	0.025	0.975	-
wk 12	0.76	0.25	0.46	0.467	0.578	0.48	0.50	0.029	0.599	
Manganese, µmol/L										
wk 0	0.05	0.07	0.06	0.028	0.836	0.06	0.06	0.005	0.376	
wk 6	0.05	0.07	0.06	0.014	0.559	0.06	0.06	0.004	0.849	> 0.036
wk 12	0.07	0.08	0.07	0.019	0.769	0.07	0.07	0.009	0.877	
Selenium, µmol/L										
wk 6*	0.89	0.80	0.87	0.238	0.917	0.55	1.16	0.028	<0.001	0.12 - 31.6
wk 12*	0.67	0.63	0.73	0.146	0.818	0.50	0.86	0.030	<0.001	
Iron, µmol/L										
wk 0	80.3	78.0	64.6	9.48	0.277	75.5	73.1	4.22	0.573	
wk 6	66.1	60.1	57.1	8.36	0.579	58.9	63.3	3.48	0.211	-
wk 12	50.3	58.4	46.8	7.96	0.390	52.1	51.6	3.43	0.887	
Cobalt, µmol/L										
wk 0	0.03	0.04	0.02	0.019	0.821	0.03	0.03	0.008	0.860	
wk 6	0.05	0.05	0.05	0.015	0.953	0.03	0.08	0.004	<0.001	0.04 - 0.08[1]
wk 12	0.05	0.05	0.03	0.025	0.802	0.02	0.06	0.008	<0.001	

*Adjusted for covariate, mean Se concentration in wk 0 = 0.44 µmol/L
[1] Range for plasma B12. One Co atom in every B12 molecule

4.6. Plasma metabolite concentrations

There was no difference (P>0.05) in plasma urea at the beginning of the study for animals receiving any the treatments, with a mean value of 5.0 mmol/L (Table 7). There was no main effect of treatment on plasma urea at wk 6 or wk 12, but there was an interaction between time and forage source for plasma urea, with values decreasing between wk 0 and wk 6 for all forage types, then decreasing between wk 6 and wk 12 for cattle fed kale and increasing for cattle fed grass.

Plasma 3-OHB concentrations in wk 0 tended (P<0.1) to be lower in cattle that were about to receive a mineral bolus, but there was no effect (P>0.05) of forage source. There was a time x forage interaction approaching significance, where in both wk 6 and wk 12 plasma 3-OHB concentrations tended (P<0.1) to be lower in heifers grazing fodder beet than kale. There was also a time x forage interaction for plasma 3-OHB, with values increasing between wk 6 and wk 12 in heifers fed kale, decreasing between wk 0 and wk 6 in heifers fed fodder beet, and decreasing at wk 6 and then increasing at wk 12 for those fed grass.

Table 7. Plasma metabolite concentrations in pregnant heifers reared outside between November 2012 and January 2013 on grass (G), kale (K) or fodder beet (F), and either did not receive (B-) or received (B+) a mineral bolus.

	G	K	F	s.e.d.	*P*-value	B-	B+	s.e.d.	*P*-value	Normal Range
Urea, mmol/L										
wk 0	5.1	5.4	4.3	1.09	0.607	5.0	4.9	0.11	0.139	
wk 6	3.6	4.7	2.9	0.78	0.127	3.7	3.7	0.09	0.789	3 - 8
wk 12	4.1	3.8	3.1	0.75	0.418	3.7	3.6	0.13	0.334	
3-OHB, mmol/L										
wk 0	0.44	0.35	0.48	0.225	0.844	0.45	0.40	0.026	0.056	
wk 6	0.28	0.37	0.33	0.089	0.627	0.33	0.33	0.015	0.857	0.25 - 0.55
wk 12	0.42	0.46	0.31	0.059	0.099	0.40	0.40	0.020	0.982	

4.7. Haematology

There was no effect of dietary treatment on red blood cell counts (RBC), although there was an interaction between time and forage source (P<0.001), with reduced RBC in week 12 on cattle grazing kale compared to fodder beet (Table 8). There was also an interaction between time, forage source and bolus (P<0.05) on haemoglobin which was reduced in wk 12 in cattle grazing kale without a bolus (11.9 and 12.8 g/dL in B- and B+ respectively for cattle grazing K). There was an interaction on plasma haematocrit between forage source and time (P<0.05), which was reduced in wk 12 in cattle grazing kale. Mean corpuscular volume tended (P<0.1) to be higher in cattle receiving kale than fodder beet in wk 6, and was higher in wk 12 (P<0.01). There was also a forage x bolus interaction (P<0.05), with lower values in cattle receiving a bolus on kale but not fodder beet or grass (46.8 and 45.3 μmm^3 in B- and B+ respectively, for cattle grazing K). White blood cell counts were higher (P<0.05) in cattle receiving a bolus during wk 6, but not wk 12. Similarly, lymphocytes were higher (P<0.05) in cattle receiving a bolus in wk 6.

Table 8. Haematology in pregnant heifers reared outside between November 2012 and January 2013 on grass (G), kale (K) or fodder beet (F), and either did not receive (B-) or received (B+) a mineral bolus

	G	K	F	s.e.d	*P*-value	B-	B+	s.e.d	*P*-value	Normal Range
Red blood cells, 10^6/ml										
wk 6*	7.2	7.9	7.4	0.36	0.342	7.4	7.5	0.15	0.299	6 - 11
wk 12*	7.1	7.3	7.7	1.08	0.770	7.3	7.4	0.15	0.747	
Haemoglobin, g/dL										
wk 6*	11.0	13.2	11.4	1.71	0.563	11.8	11.9	0.24	0.713	8 - 15
wk 12*	11.2	12.2	11.5	1.76	0.894	11.7	11.6	0.26	0.565	
Haematocrit, %										
wk 6*	29.3	36.3	30.6	3.34	0.251	32.0	32.1	0.69	0.87	25 - 50
wk 12*	30.0	34.2	32.1	4.99	0.796	32.4	31.8	0.70	0.427	
Mean corpuscular volume, μmm^3										
wk 0	45.3	44.1	43.1	1.16	0.260	44.1	44.2	0.78	0.313	
wk 6	44.1	47.1	42.0	1.86	0.090	44.6	44.2	0.34	0.211	40 - 60
wk 12	43.6	46.5	41.9	0.83	0.004	44.6	43.5	0.32	<0.001	
White blood cells, $10^3/mm^3$										
wk 0	9.1	8.0	9.1	1.19	0.568	8.9	8.6	0.48	0.583	
wk 6	8.1	9.2	9.0	0.80	0.380	8.4	9.1	0.31	0.023	4 - 15
wk 12	7.7	8.4	7.9	0.36	0.232	7.9	8.1	0.26	0.543	
Lymphocytes, $10^3/mm^3$										
wk 0	4.3	4.5	5.0	0.87	0.759	4.7	4.5	0.35	0.594	
wk 6	4.6	4.7	5.3	0.35	0.191	4.6	5.1	0.20	0.035	1.8 - 12
wk 12	4.0	4.1	4.1	0.22	0.884	4.0	4.2	0.16	0.386	

*Adjusted for covariate, mean number of red blood cells in wk 0 = 8.4×10^6/ml, mean haemoglobin concentration in wk 0 = 13.3 g/dL, mean haematocrit in wk 0 = 36.0%

4.8. Lactation performance at week 10 and 19 post-calving

There was no effect of forage source on milk yield or somatic cell count at wk 10 or wk 19 of lactation, with mean values of 18.0 and 15.8 kg/d respectively (Table 9). There was a forage x bolus interaction (P<0.05) for milk fat concentration (g/kg) in wk 10, with higher values in cattle receiving a bolus when grazing kale (38.2 and 42.2 g/kg in B- and B+ respectively for cattle which had grazed K). Fat corrected milk yield (FCM) tended (P<0.1) to be higher in B+ than B- at week 10 of lactation, and there was also a trend (P=0.1) for milk yield to be higher at wk 19 of lactation in first lactation cows that had received a trace mineral bolus during late gestation.

Table 9. Milk performance of replacement heifers that had been reared outside between November 2012 and January 2013 on grass (G), kale (K) or fodder beet (F), and either did not receive (B-) or received (B+) a mineral bolus.

	G	K	F	s.e.d.	*P*-value	B-	B+	s.e.d.	*P*-value
Week 10 of lactation									
Milk yield, kg/d	18.2	19.2	16.4	1.85	0.390	17.8	18.1	0.35	0.394
FCM, kg/d	18.6	19.5	17.1	1.98	0.526	18.1	18.7	0.39	0.087
Fat, g/kg	41.7	40.2	43.0	0.22	0.549	40.7	42.6	0.71	0.009
Protein, g/kg	33.8	34.3	34.2	1.48	0.925	34.2	34.0	0.25	0.625
Fat, kg/d	0.76	0.77	0.70	0.082	0.659	0.73	0.76	0.020	0.107
Protein, kg/d	0.61	0.66	0.56	0.072	0.587	0.61	0.62	0.013	0.459
SCC, $\log_{10}$	1.74	1.76	1.81	0.086	0.605	1.78	1.76	0.043	0.593
Week 19 of lactation									
Milk yield, kg/d	17.1	15.6	14.8	1.64	0.418	15.6	16.0	0.29	0.100
FCM, kg/d	18.2	16.6	16.3	2.24	0.680	16.8	17.2	0.30	0.108
Fat, g/kg	44.6	44.3	47.2	2.83	0.556	45.4	45.3	0.61	0.866
Protein, g/kg	35.6	35.7	37.2	1.47	0.483	36.3	36.1	14.71	0.452
Fat, kg/d	0.76	0.69	0.69	0.107	0.791	0.70	0.72	0.013	0.152
Protein, kg/d	0.61	0.56	0.55	0.075	0.708	0.56	0.58	0.010	0.200
SCC, $\log_{10}$	1.99	1.82	1.67	0.295	0.573	1.86	1.80	0.042	0.156

4.9. Body condition at week 10 and 19 post-calving

There was no effect (P>0.05) of forage source during the out-wintering period or the provision of a trace mineral bolus on mean body condition score at wk 10 or wk 19 of lactation (Table10), although there was a tendency (P<0.1) for body condition score to be lower in heifers that had been out-wintered on fodder beet. Overall, body condition score increased (P<0.001) by 0.125 between wk 10 and 19 of lactation.

Table 10. Body condition at weeks 10 and 19 of lactation of replacement heifers that had been reared outside between November 2012 and January 2013 on grass (G), kale (K) or fodder beet (F), and either did not receive (B-) or received (B+) a mineral bolus.

	G	K	F	s.e.d.	*P*-value	B-	B+	s.e.d.	*P*-value
Week 10 of lactation	2.13	2.02	2.03	0.075	0.332	2.07	2.05	0.025	0.611
Week 19 of lactation	2.25	2.20	2.10	0.053	0.068	2.18	2.19	0.020	0.787

4.10. Animal health

The incidence of animal health problems are presented in Table 11. There was no main effect of forage source or the provision of a trace element bolus on any of the parameters measured. There was a main effect of time with lameness which increased between visits 1 and 3 (Prob.=2% and 7% visit 1 and 3 respectively, P=0.009, OR =0.3, 95% CI=0.15-0.76).

Table 11. Health of replacement heifers that had been reared outside between November 2012 and January 2013 on grass (G), kale (K) or fodder beet (F), and either did not receive (B-) or received (B+) a mineral bolus.

		Probability	OR	95% CI	P-value
lame pre-calving					
	G	2%	1.0	ref.	ref.
	K	3%	0.7	0.05-9.10	0.742
	F	7%	0.3	0.02-3.39	0.246
	B-	3%	1.0	ref.	ref.
	B+	4%	0.6	0.30-1.21	0.157
lame post-calving					
	G	13%	1.0	ref.	ref.
	K	19%	0.6	0.19-2.00	0.347
	F	16%	0.8	0.23-2.46	0.575
	B-	16%	1.0	ref.	ref.
	B+	15%	1.1	0.69-1.81	0.658
calved unassisted					
	G	90%	1.0	ref.	ref.
	K	84%	1.8	0.25-13.04	0.471
	F	94%	0.6	0.08-4.33	0.539
	B-	90%	1.0	ref.	ref.
	B+	91%	0.9	0.45-1.77	0.740
Endometritis					
	G	12%	1.0	ref.	ref.
	K	21%	0.5	0.06-4.67	0.470
	F	6%	2.2	0.24-19.69	0.413
	B-	12%	1.0	ref.	ref.
	B+	12%	1.0	0.51-1.92	0.972
clinical mastitis					
	G	5%	1.0	ref.	ref.
	K	10%	0.5	0.16-1.48	0.203
	F	4%	1.2	0.40-3.65	0.737
	B-	6%	1.0	ref.	ref.
	B+	6%	1.2	0.47-2.89	0.733

4.11. Reproductive performance

Measures of reproductive performance are presented in Table 12. The mating period ranged from 16 to 9 weeks in length between farms. There was no main effect of forage source or the provision of a trace element bolus on any of the parameters measured, except for the proportion of cows that were in-calf at the end of the mating period, which was higher in animals that had been reared on fodder beet than those on kale or grass. There was also a forage x bolus interaction with animals on kale without bolus, more likely to receive fertility treatment than animals on farms with fodder beet (Prob.=41%, P=0.030, OR =4.9, 95% CI=0.82-29.49).

Table 12. Fertility performance of replacement heifers that had been reared outside between November 2012 and January 2013 on grass (G), kale (K) or fodder beet (F), and either did not receive (B-) or received (B+) a mineral bolus.

		Probability	OR	95% CI	P-value
cycling at start of mating					
	G	76%	1.0	ref.	ref.
	K	82%	0.7	0.09-5.28	0.673
	F	53%	2.8	0.37-21.76	0.254
	B-	75%	1.0	ref.	ref.
	B+	69%	1.3	0.85-2.03	0.225
received fertility treatment					
	G	33%	1.0	ref.	ref.
	K	20%	1.9	0.31-11.85	0.415
	F	12%	3.5	0.57-21.70	0.143
	B-	22%	1.0	ref.	ref.
	B+	19%	1.2	0.72-1.94	0.521
returned to first service					
	G	57%	1.0	ref.	ref.
	K	57%	1.0	0.52-1.97	0.967
	F	52%	1.2	0.63-2.39	0.487
	B-	54%	1.0	ref.	ref.
	B+	57%	0.9	0.63-1.30	0.572
in-calf at end of mating					
	G	88%	1.0	ref.	ref.
	K	86%	1.2	0.48-2.90	0.718
	F	95%	0.4	0.15-0.92	0.032
	B-	90%	1.0	ref.	ref.
	B+	91%	0.3	0.42-1.86	0.748

4.12. Soil parameters

Soil measurements undertaken pre- and post-grazing in November, December and January are presented in Table 13, and the main effects pre- and post-grazing in Figures 1-4. There was no effect (P>0.05) of forage source on surface roughness, soil bulk density, volumetric water content or gravimetric water content, and there was no interaction (P>0.05) between forage type and pre- and post-measurements. There was an effect of grazing on soil roughness (P<0.05), which increased by approximately 16.5 cm/m post-grazing in Nov, Dec and Jan. Similarly, bulk density increased post-grazing throughout the winter grazing period. Volumetric water content also increased post grazing in January (P<0.05) and tended (P<0.1) to increase in December. In contrast, gravimetric water content was not affected by grazing, although it tended (P<0.1) to be increased in December.

Table 13. Soil parameters on grass (G), kale (K) or fodder beet (F) fields grazed by replacement heifers reared between November 2012 and January 2013.

	G	K	F	s.e.d.	*P*-value	Pre-grazing	Post-grazing	s.e.d.	*P*-value
Surface roughness (cm of chain > 1 m)									
Nov	8.9	11.7	12.8	4.48	0.688	4.4	17.8	3.84	0.025
Dec	12.7	11.8	14.3	2.16	0.543	3.6	22.2	2.39	<0.001
Jan	9.8	13.9	14.7	3.75	0.421	3.8	21.7	2.92	<0.001
Soil dry bulk density (g/cm^3									
Nov	1.23	1.33	1.19	0.150	0.662	1.21	1.30	0.035	0.047
Dec	1.30	1.26	1.22	0.143	0.862	1.26	1.26	0.024	0.873
Jan	1.20	1.30	1.14	0.175	0.675	1.20	1.23	0.021	0.279
Soil moisture content (vol/vol)									
Nov	39.3	30.6	41.4	5.54	0.200	35.6	38.6	1.73	0.157
Dec	43.3	32.0	35.8	6.85	0.311	34.8	39.2	1.89	0.081
Jan	43.5	38.1	36.8	4.26	0.314	36.5	42.4	2.07	0.036
Soil moisture content (g/g)									
Nov	25.7	19.1	25.7	4.67	0.327	23.2	23.8	0.63	0.397
Dec	26.2	19.6	22.7	4.97	0.463	21.8	23.9	0.96	0.097
Jan	27.1	22.8	24.6	4.14	0.608	23.3	26.3	1.50	0.107

5. Conclusions

Growth performance pre-calving was very variable between and within farms during the out-wintering period and there was little difference between animals reared on deferred grazing, kale or fodder beet. The provision of a trace mineral bolus increased blood concentrations of the minerals supplied in the bolus, but there was little effect on animal performance, except body condition prior to calving which was higher in animals receiving a bolus. There was no effect of winter forage source on milk performance, but the mineral bolus increased milk fat content, and tended to increase fat corrected milk yield, particularly in farms grazing kale. There was no effect of treatment on health or reproductive performance, except for the overall percentage conceived, which was higher in farms that had fed fodder beet during the rearing period. Finally, there was no difference in soil conditions on farms out-wintering on grass, kale or fodder beet, with a similar increase in soil compaction post-grazing on all three systems.

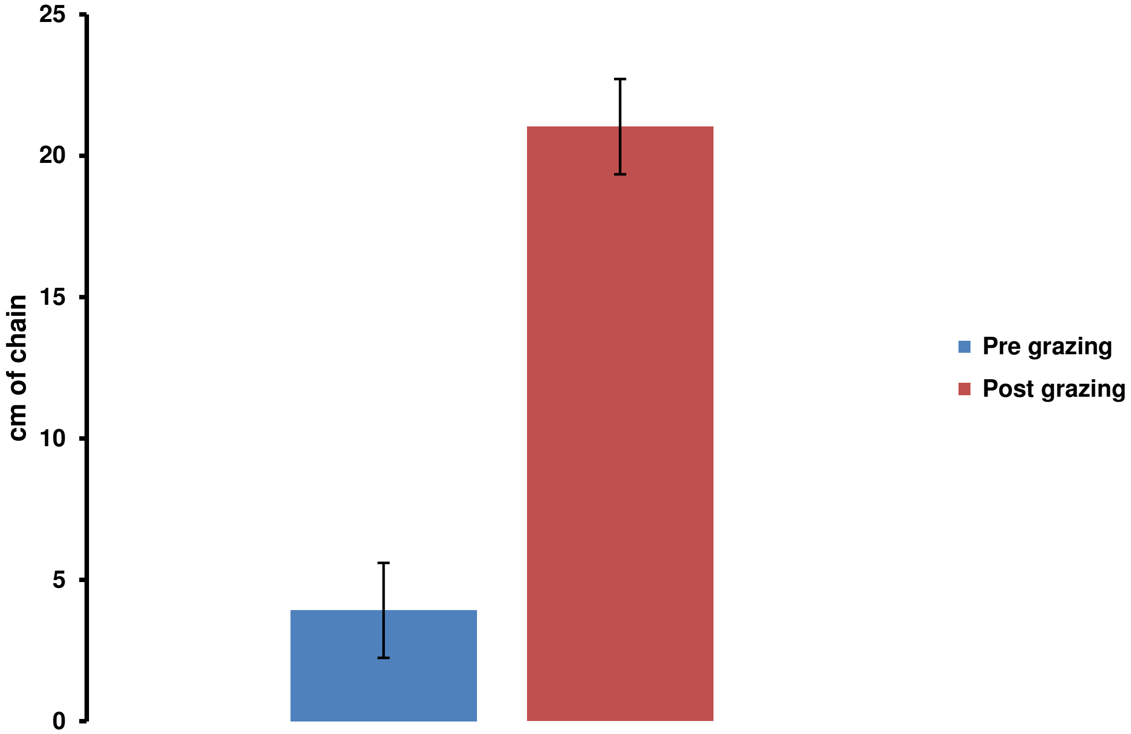

Figure 1. Soil surface roughness (cm of chain > 1 m), pre and post grazing by out-wintering heifers. Post grazing (21.0 cm) soil surface is rougher than pre grazing (3.9 cm) soil surface (P<0.001, d.f. 23, s.e.d 1.69)

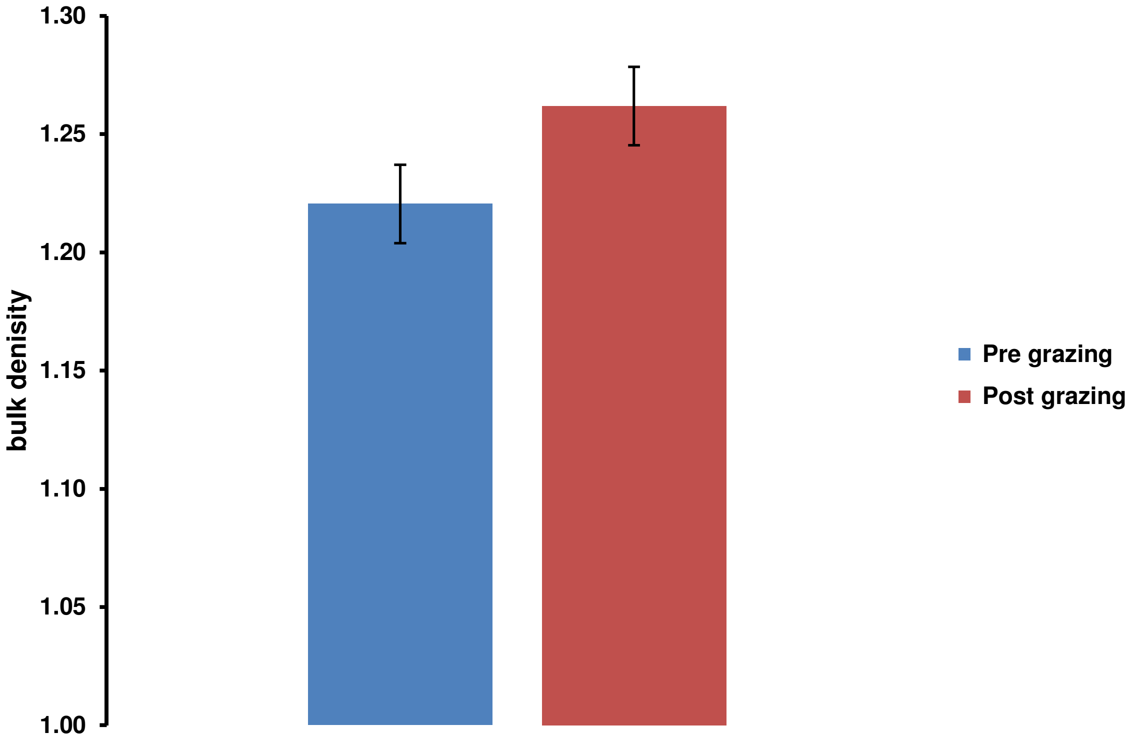

Figure 2. Soil dry bulk density pre and post grazing by out-wintered heifers. Post grazing (1.26) bulk density is greater than pre grazing (1.22) bulk density (P=0.020, d.f. 23, s.e.d 0.017)

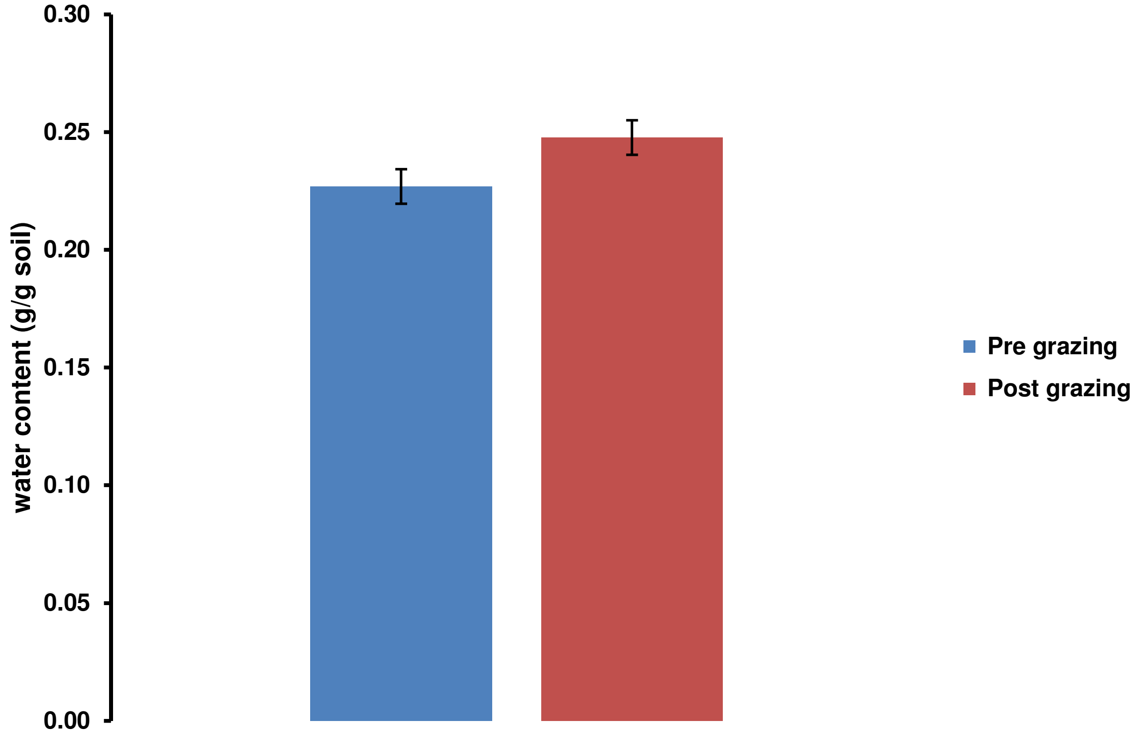

Figure 3. Soil gravimetric water content pre and post grazing by out-wintered heifers. Post grazing (0.25) soil moisture is greater than pre grazing (0.23) soil moisture (P=0.010, d.f. 23, s.e.d 0.007)

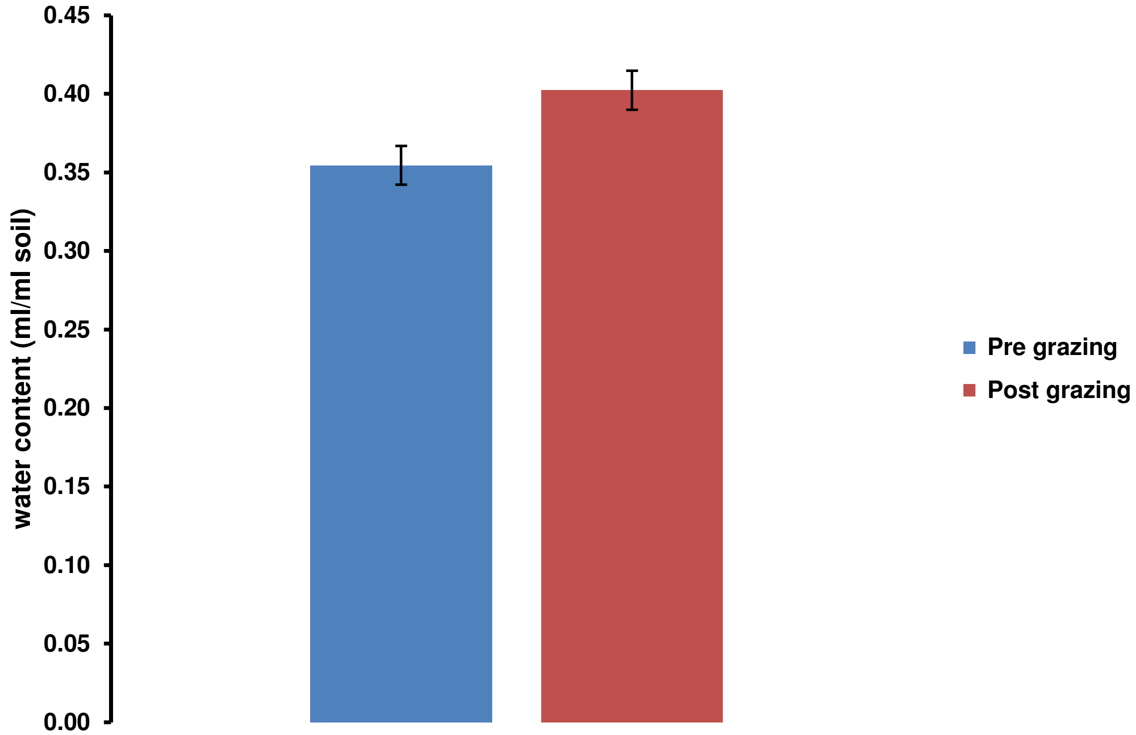

Figure 4. Soil volumetric water content pre and post grazing by out-wintered heifers. Post grazing (0.40) soil moisture is greater than pre grazing (0.35) soil moisture (P<0.001, d.f. 23, s.e.d 0.012)

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