Grazing management practices and pasture composition on Waikato and Canterbury dairy farms diverging in bulk milk urea content

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Abstract

New Zealand dairy farmers have little real-time information on surplus nitrogen (N) in their herd's diet to help manage farm-scale N loss. By understanding the influence of management on bulk milk urea (BMU), farmers could potentially use milk components to identify changes in dietary N surplus. Our study examined the relationships between grazing management and BMU concentration on 38 dairy farms selected for low or high BMU in Canterbury and Waikato. Measurements included pre- and post-grazing herbage mass, perennial ryegrass leaf stage at grazing, and botanical and chemical composition (crude protein (CP) and metabolisable energy (ME) content) of herbage on four occasions over a year. Herds with Low BMU tended to graze pastures with a greater pre-grazing herbage mass (+153 kg DM/ha), a more advanced leaf stage (+0.13 number of leaves), and longer grazing intervals (+11 days). Consistent with this, herbage on Low BMU farms had lower CP (-2.7%) compared with High BMU farms. We identified grazing management differences between Low and High BMU groups, which could be linked to reductions in N surplus in the herd's diet through the lower CP% of pasture offered. Future work should determine the importance of this in relation to other farm management factors such as supplement and N fertiliser use.

Keywords: grazing interval, leaf stage, botanical composition, nitrogen surplus, pasture crude protein.

Background

In grazed dairy farm systems where nitrogen (N) surpluses exist (i.e., N inputs exceed N outputs), distribution of the surplus N occurs primarily through deposition in cow urine patches (Selbie et al. 2015). The N from these urine patches is at risk of leaching and contaminating waterways, and contributing to atmospheric greenhouse gas emissions (e.g., nitrous oxide; Di and Cameron (2008)). Although there are various mitigation strategies to reduce farm-scale N loss, many of these mitigations are reported at a strategic level, e.g., reduced annual N fertiliser and purchased feed inputs. Farmers currently receive little feedback on how well their herd's dietary N surplus is being managed on a week-by-week basis.

Overseas research indicates that milk urea concentration is a useful proxy for urinary N excretion and is correlated with dietary N intake when animals are offered diets with little or no grazed pasture (Jonker et al. 1998; Spek et al. 2013). New Zealand dairy farmers can access farm-level bulk milk urea (BMU) concentrations for each milk collection through their milk processors. Does this mean milk urea could be a useful indicator of dietary N surplus and urinary N loss risk in grazing systems?

The aim of our wider research study was to identify key farm management factors associated with divergent BMU concentrations in commercial dairy farms across a lactation season and to understand sources of variation in BMU between farms and regions. In this paper, we describe the grazing management practices of farms diverging in BMU concentration to determine if these practices are associated with differences in the chemical and botanical composition of the pasture offered to herds. An understanding of the influence of grazing management drivers on BMU could allow farmers to use this information, along with other farm management variables, to apply appropriate strategic and tactical mitigations for reducing dietary N surplus. We used an observational case study approach for Waikato and Canterbury dairy farms selected for divergent BMU concentrations based on historical milk data. The study also provided a regional comparison of how farms conformed with recommended grazing practices.

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Approach

Farm selection

Fonterra provided data for the top 50 and bottom 50 farms in both Waikato and Canterbury ranked on annual average BMU concentrations for the previous five seasons (2016-17 to 2020-21). From this, sub-groups of farms with historically "High" or "Low" BMU for each region were created by excluding farms:

1. more than two hours driving distance one way from the nearest DairyNZ research base and from districts with very few farms;
2. with identified data quality issues, such as missing data;
3. with less than 150 cows; or
4. with milksolids (MS; milk fat plus protein) production less than 300 kg MS/cow/year.

Farmers were first contacted by Fonterra staff in October 2021 to determine if they were open to being contacted by the project team. Farmers were then contacted by DairyNZ project staff. In the Waikato, COVID restrictions meant this involved a phone call, whereas in Canterbury on-farm visits were possible. The BMU groupings were checked to ensure mean MS production per ha, effective area and herd size were similar within region. A total of 38 farms were enrolled in the study. The farm system characteristics for the groups for the 2020-21 season prior to the monitoring period are provided in Table 1.

Each farm was visited on four occasions for sample and data collection. The timing of these visits is described in Table 2. COVID restrictions delayed the visits in early spring 2021. Therefore, visits coincided with late spring, summer and autumn of the 2021-22 lactation season and early spring 2022-23 lactation (the monitoring period).

Table 1 Averages (and standard deviations) for farm system characteristics of the 38 selected dairy farms for the 2020-21 season (one year prior to case study), split between region and High vs Low annual average bulk milk urea (BMU) groups. Data source: Farm Insights reports, which contain annually reported Farm Dairy Records for each farm provided by Fonterra.

2020-21 Farm Characteristics	Waikato			Canterbury		
	High BMU (n=9)	Low BMU (n=9)	P-value[1]	High BMU (n=9)	Low BMU (n=11)	P-value[1]
Average BMU (mg/dL)	35.0 (1.45)	21.5 (3.02)	<0.001	31.4 (2.51)	21.5 (1.67)	<0.001
Effective area (ha)	138 (58.2)	160 (79.7)	0.6	199 (75.9)	190 (72.2)	0.7
Peak cow number	409 (143.0)	427 (151.4)	0.9	719 (272.4)	632 (268.6)	0.4
Stocking rate (cows/ha)	3.0 (0.42)	2.9 (0.63)	0.7	3.6 (0.24)	3.3 (0.57)	0.020
Production (kg MS[2]/cow)	382 (116.0)	412 (54.0)	0.063	436 (40.1)	449 (47.0)	0.4
Production per hectare (kg MS/ha)	1,154 (343.7)	1,186 (274.4)	0.7	1,580 (161.7)	1,491 (347.7)	0.7
Annual nitrogen fertiliser (kg N/ha/yr)	135 (37.6)	106 (44.8)	0.094	226 (23.9)	157 (58.1)	<0.001
Imported feed (kg DM/cow)	589 (846.2)	1,311 (1069.4)	0.033	511 (379.0)	782 (453.5)	0.2
Purchased nitrogen surplus[3] (kg N/ha)	99 (48.4)	110 (67.5)	0.7	147 (33.2)	103 (55.3)	0.074

[1] Wilcoxon rank sum exact test; Wilcoxon rank sum test

[2] MS = milksolids (milk fat plus protein)

[3] Purchased nitrogen surplus = (N in fertiliser + purchased N in feed) – N in outputs (milk, meat, supplement).

Table 2 Dates of four visits to collect pasture, bulk milk, and other farm management information across 38 Waikato and Canterbury dairy farms in the 2021-22 lactation season (visits 1 to 3) and 2022-23 lactation (visit 4).

	Waikato		Canterbury	
	Start	End	Start	End
Visit 1: Late spring	10/11/2021	21/12/2021	22/11/2021	27/01/2022
Visit 2: Summer	2/02/2022	25/03/2022	2/02/2022	17/03/2022
Visit 3: Autumn	30/03/2022	11/05/2022	31/03/2022	19/05/2022
Visit 4: Early spring	13/09/2022	18/10/2022	1/09/2022	17/10/2022

At each visit, relevant farm management data were collected, including the number of days since a paddock was last grazed (grazing interval). Samples of pasture (2 kg approx. fresh weight (fw)) were taken, by cutting to 4 cm (grazing height) using battery powered shearing handpieces, from the next three areas of pasture to be allocated to the herd. Sub-sampling took place within a day of collection for botanical composition (30 g fw) and laboratory analysis (up to 500 g fw). Botanical composition of each sample was determined using the method described in Anderson et al. (2019).

Fresh pasture samples were submitted to a commercial laboratory for feed quality analysis (Hill Laboratories, New Zealand). In brief, samples were oven dried at 62°C overnight and then ground to pass through a 1 mm screen. Crude protein content (CP) was calculated from N% (estimated by near infrared (NIR) spectroscopy (MPA FT-NIR Analyzer, Bruker Optics, Billerica, MA), with calibration based on total N by Dumas combustion) multiplied by 6.25. Metabolisable energy (ME) was calculated from dry organic matter digestibility (DOMD; estimated by NIR) using the following calculation, ME = 0.16 x DOMD.

An additional ten samples per paddock were taken for perennial ryegrass leaf stage assessment using a craft knife to cut bunches of non-reproductive perennial ryegrass tillers at ground level. Leaf stage was assessed by trained DairyNZ staff counting the leaves of 10 tillers selected from each paddock sample and reporting the mean leaf stage (Fulkerson and Donaghy 2001; McCarthy et al. 2015).

Pre-grazing herbage mass for the next three areas of pasture to be allocated to each herd was measured using a standardised electronic rising plate meter (Jenquip EC09, Feilding, New Zealand), with a minimum of 80 readings per allocated area. Post-grazing herbage mass was estimated at each visit in the two most recently grazed allocations of pasture using the same rising plate meter and calibration equation. The following calibration equation was used for all visits with no seasonal adjustment. Pasture mass (kg DM/ha) = (140 × mean compressed height) + 500 (L'Huillier and Thomson 1988).

For each farm, bulk milk composition data (urea, MS, fat, protein, milk volume etc.) were available from each Fonterra tanker collection relevant to each visit. Milk composition was analysed at the MilkTestNZ laboratory in Hamilton using FOSS Mid Infrared MilkoScans (Foss Electric A/S, Hillerød, Denmark). The measurement period for each visit was determined using the time cows entered the first area of pasture sampled and the date the cows left the last area of pasture sampled for that visit. Bulk milk and pasture data were averaged across the measurement period per farm per visit. For bulk milk data, this averaging considered the timing of milk collection relative to milkings while cows were grazing sampled pastures, so that milk data were representative of the pastures sampled.

Statistical analyses

Data analysis were performed in R (versions 4.2.0-2, R software, R Core Team (2022)). Uncommon botanical categories (herbs, other legume, other grass and C4 grasses) were collapsed into one category called 'Other %'. The distributions of variables were explored visually, and descriptive statistics were calculated (mean and standard deviation (SD)) by region, BMU group and visit. The distributions of variables of interest were compared across High and Low BMU groups, visits, and regions, and across combinations of those groups. Differences between groups were tested by Student's T test when data were normally distributed and the Wilcoxon rank-sum or Wilcoxon rank-sum exact test when not.

Results and Discussion

Bulk milk urea divergence

During the monitoring period (visits 1 to 4), the High and Low BMU farms maintained a significant difference in mean (±SD) BMU concentration (High = 29.0 ± 7.08 mg/dL, Low = 18.2 ± 5.95 mg/dL; $P<0.001$), although both groups had lower BMU concentrations compared with the annual averages from the previous 2020-21 season (Table 1).

Comparison of pre- and post-grazing herbage mass

There was a trend ($P=0.052$) for overall mean pre-grazing herbage mass (averaged across regions and visits) to be greater for the Low BMU farms than the High BMU farms, with the Low BMU group in the Waikato being influential during early and late spring (Table 3). Post-grazing herbage mass did not differ between High and Low BMU farms (Table 3).

Mean pre-and post-grazing herbage masses (kg DM/ha ± SD) were significantly greater ($P<0.001$) in Canterbury (pre-graze, 2978 ± 605; post-graze, 1754 ± 153) than in Waikato (pre-graze, 2642 ±368; post-graze, 1641 ± 296). Pre-graze herbage mass in Waikato was well below industry recommended targets of 2800-3200 kg DM/ha (DairyNZ 2023) due to drought in summer and autumn of the 2021-22 season (Table 3). By contrast, all Canterbury farms had access to irrigation resulting in relatively consistent mean pre-grazing herbage masses across spring, summer and autumn seasonal visits, and no significant differences between High and Low BMU farms within seasonal visits in this region (Table 3). Furthermore, pre-grazing herbage masses in Canterbury were within the industry recommended range of 2800 to 3200 kg DM/

ha (DairyNZ 2023), except for the High BMU farms in early spring, which were slightly below this range.

Post-grazing residuals often exceeded target levels of 1500-1600 kg DM/ha (DairyNZ 2023) except for Waikato in summer and autumn, where they were slightly below target most likely due to low soil moisture limiting pasture availability (Table 3).

Leaf stage at grazing

There was an overall trend for a more advanced leaf stage at grazing on Low BMU farms compared with High BMU farms (P=0.084; Table 4). This was driven by the significant difference in leaf stage between BMU groups in Canterbury in early spring when Low BMU farms had an additional 0.5 leaves at grazing compared with High BMU farms (Table 4). There were no significant differences between the High and Low BMU groups in Waikato for leaf stage at grazing at any of the seasonal visits (Table 4). Compared with Waikato, Canterbury farms had, on average, a greater leaf stage at grazing (2.40 ± 0.35 vs 2.01 ± 0.37; P<0.001). On Canterbury farms, mean leaf stage was above the recommended minimum 2-leaf stage in all seasons. In contrast, mean leaf stage was below 2.0 on Waikato farms, except in summer and autumn for Low BMU farms and in autumn for High BMU farms. Grazing before the 2-leaf stage for ryegrass would be expected to increase the N content of the pasture eaten (Fulkerson and Donaghy 2001; Kumara et al. 2022).

Table 3 Pre- and post-grazing herbage mass (kg DM/ha ± SD) on participating Waikato and Canterbury dairy farms during the late spring 2021, summer 2021-22, autumn 2022, and early spring 2022. Herbage mass is estimated using the rising plate standard formula: compressed height (0.5 cm) x 140 + 500 = kg DM/ha.

		Historic bulk milk urea status		
Region	Visit	High mean ± SD	Low mean ± SD	P-value
Overall group means for all regions and visits				
Pre-grazing herbage mass		2,740 ± 421	2,893 ± 588	0.052
Post-grazing herbage mass		1,683 ± 217	1,718 ± 254	0.185
Pre-grazing herbage mass				
Waikato	Late spring	3005 ± 202	3344 ± 467	0.072
	Summer	2183 ± 256	2171 ± 471	0.949
	Autumn	2226 ± 187	2095 ± 210	0.209
	Early spring	2783 ± 344	3220 ± 607	0.083
Canterbury	Late spring	2978 ± 432	3135 ± 589	0.501
	Summer	2997 ± 298	3035 ± 239	0.762
	Autumn	2927 ± 281	2969 ± 358	0.768
	Early spring	2766 ± 264	2969 ± 356	0.160
Post-grazing herbage mass				
Waikato	Late spring	1870 ± 213	1853 ± 214	0.864
	Summer	1493 ± 187	1449 ± 384	0.767
	Autumn	1484 ± 231	1462 ± 213	0.848
	Early spring	1661 ± 205	1817 ± 292	0.210
Canterbury	Late spring	1684 ± 185	1805 ± 213	0.192
	Summer	1872 ± 166	1814 ± 130	0.406
	Autumn	1707 ± 78	1738 ± 73	0.376
	Early spring	1668 ± 123	1731 ± 136	0.291

Table 4 Mean leaf stage ± SD and grazing interval for participating farms in Waikato and Canterbury across season during late spring, summer, autumn, and early spring.

Region	Visit	Historic bulk milk urea status High mean ± SD	 Low mean ± SD	P-value
Overall group means for all regions and visits				
Mean leaf stage for ryegrass tillers		2.15 ± 0.37	2.28 ± 0.43	0.084
Grazing interval (days since last grazed)		29 ± 15	40 ± 31	0.026
Mean leaf stage for ryegrass tillers				
Waikato	Late spring	1.87 ± 0.18	1.95 ± 0.18	0.356
	Summer	1.91 ± 0.41	2.10 ± 0.41	0.347
	Autumn	2.44 ± 0.33	2.35 ± 0.33	0.606
	Early spring	1.70 ± 0.19	1.83 ± 0.19	0.149
Canterbury	Late spring	2.21 ± 0.31	2.27 ± 0.31	0.685
	Summer	2.40± 0.21	2.50 ± 0.21	0.858
	Autumn	2.20 ± 0.24	2.20 ± 0.29	1.000
	Early spring	2.44 ± 0.38	2.93 ± 0.22	0.004
Mean grazing interval (days)				
Waikato	Late spring	18 ± 3.3	21 ± 2.3	0.092
	Summer	27 ± 8.0	29 ± 5.3	0.382
	Autumn	36 ± 10.3	34 ± 10.2	0.731
	Early spring	22 ± 3.6	29 ± 6.9	0.010
Canterbury	Late spring	21 ± 2.7	22 ± 5.9	0.879
	Summer	26 ± 5.0	28 ± 5.8	0.341
	Autumn	37 ± 8.2	34 ± 5.2	0.402
	Early spring	44 ± 31.8	108 ± 30.7	0.001

Grazing interval (days since last grazing) is a key factor influencing leaf stage and pre-grazing herbage mass; therefore, we also investigated differences in duration since last grazing between BMU groups. Across all visits and regions, grazing interval was, on average, 11 days longer for the Low BMU group relative to the High BMU (P=0.026; Table 4). Grazing interval was significantly longer, on average, on Canterbury farms, than Waikato farms (41 ± 32 days vs 27 ± 8 days, respectively; P=0.004). In early spring, some farms in Canterbury were still on their first grazing rotation after a long winter break from grazing, so very high grazing intervals for these farms at this sampling influenced these leaf stage and grazing interval results. During winter, Canterbury herds are mostly grazed off pasture and away from the dairy grazing platform whereas Waikato herds are usually grazed on the platform during winter, resulting in shorter grazing intervals between winter and spring grazing. Removing the Canterbury early spring (visit 4) data for grazing interval from the analysis reduces the grazing interval difference between Low BMU and High BMU groups from +11 days (P=0.026) to a trend (+1.6 days, P=0.086).

Despite the lower leaf stage at grazing and shorter grazing interval, Waikato farms achieved, on average, adequate pre-grazing herbage mass in early and late spring suggesting that the addition of N fertiliser is likely to have had a role. Nitrogen fertiliser increases pasture mass for each leaf stage, with little effect on leaf emergence rate (Lee et al. 2007). Potentially, N fertiliser could have further elevated the already high N content of the low leaf stage herbage offered. The role of N fertiliser timing and application rate requires further investigation relative to other aspects of farm management and divergent BMU in these case study herds.

Botanical composition

There were no differences in the botanical composition of pastures between High and Low BMU groups when averaged across both regions and all visits (data not shown). However, there were some differences in botanical composition between regions and between High and Low BMU farms within region (Table 5). Canterbury pastures had a greater proportion of perennial ryegrass overall than Waikato (+19.8%; P<0.001), driven by differences at the late spring, summer and autumn visits. Canterbury also had a lower proportion of 'other' species (-12.3%; P<0.001) and dead matter (8.4%; P<0.001) overall compared with Waikato, particularly in the late spring, summer and autumn visits (P<0.05; Table 5). The greater proportion of 'other' pasture species in the Waikato at these times reflects the presence of C4 summer grass. The proportion of white clover in the pasture was greater in Canterbury during the summer (+3.7%; P=0.013), but in autumn the proportion was greater in Waikato (+7.6%; P<0.001). There was greater weed content in Canterbury pastures at the late spring and summer visits (P<0.01). Botanical composition of pasture was most similar between regions in early spring.

In Waikato, there were no overall or seasonal differences in perennial ryegrass content between divergent BMU farms (Table 5). In contrast, Canterbury farms with Low BMU had, on average, less perennial ryegrass and tended to have greater white clover contents in pasture compared with High BMU farms, but these differences were only significant in summer (P<0.05). Across all seasonal visits, Waikato farms with Low BMU concentrations had, on average, a lower white clover pasture content; however, this difference was only significant in summer with a trend (P=0.082) in late spring (Table 5). These differences are potentially important as the proportion of white clover in the diet of dairy cows changes the utilisation of dietary protein in the rumen (Cosgrove et al. 2006) and influences milk production, milk composition and milk indicators of protein utilisation.

The proportion of dead material in pasture was greater in the Waikato Low BMU farms in late spring, but similar at other seasonal visits (Table 5). There was a trend (P=0.084) for the Waikato Low BMU farms to have a greater proportion of pasture species classified as 'other' in autumn (i.e., herbs and C4 grasses). An increase in these pasture components for Waikato is consistent with a lower measured ME content (0.9 MJ ME/kg DM; P<0.001) compared with Canterbury pastures and reflects the influence of irrigation in Canterbury. There were no overall or seasonal visit differences in dead matter, weeds and 'other' content in the pasture between High and Low BMU farms in Canterbury. The implications of these regional differences in botanical composition for seasonal variation in BMU concentration have yet to be fully explored.

Pasture crude protein and metabolisable energy content

Pasture CP content differed between High and Low BMU groups with 2.7% lower mean pasture CP content on the Low BMU farms (P<0.001; Table 6). Lower pasture CP for Low BMU farms was particularly apparent in Waikato in late spring (P<0.001), autumn (P=0.05) and early spring (P=0.001), and in Canterbury in early spring (P=0.001) with trends in Canterbury for late spring and summer (P<0.100; Table 6). There was no difference in CP content overall between regions despite the summer drought in Waikato lowering the CP content in that region, compared with Canterbury (data not shown).

Overall pasture ME was not different between High and Low BMU group farms (Table 6). Within region, the only significant difference in ME observed between High and Low BMU groups was Waikato in late spring with 10.6 and 9.8 MJ ME/kg DM, respectively (P=0.043).

There was a significant regional difference in ME content overall, with mean values of 10.6 and 11.5 MJME/kg DM for Waikato and Canterbury, respectively (P<0.001). The higher ME content of pasture in Canterbury reflects the influence of irrigation in Canterbury on pasture quality and could be important for how Canterbury herds manage any dietary N surplus resulting from the dietary CP levels. Additionally, the greater content of 'other' pasture species (e.g. herbs and C4 grasses) in Waikato pastures is consistent with their lower ME content (0.9 MJ ME/kg DM) compared with Canterbury pastures. Subtropical C4 grasses have lower nutritive value (both CP and ME) than perennial ryegrass (Jackson et al. 1996).

Longer grazing intervals on the Low BMU farms is consistent with the trend for increased leaf stage and pre-grazing herbage mass at grazing. These are all likely to have been drivers behind the lower pasture CP content on the Low BMU farms. This is consistent with Kumara et al. (2022) who reported lower CP and ME content of pasture with higher pre-grazing herbage mass (>3000 kg DM/ha), and with increased leaf stage above 3. They also determined that ME and CP were negatively correlated with both neutral detergent fibre and acid detergent fibre suggesting that longer grazing

Table 5 Botanical composition (% of dry matter ± SD) by season for each region, and for High and Low BMU farms within Waikato and Canterbury regions. Other % included herbs, legume other than white clover, grass other than perennial ryegrass including C4 grasses.

Variable	Visit	Region			Waikato			Canterbury		
		Waikato	Canterbury	P-value	High	Low	P-value	High	Low	P-value
Perennial ryegrass %	Overall (whole year)	58.8 ± 23	78.6 ± 12	<0.001	61.0 ± 22	56.5 ± 24	0.5	82.9 ± 6	75.1 ± 15	0.014
White clover %		7.1 ± 6	6.0 ± 4	0.6	9.1 ± 7	5.0 ± 4	0.001	4.8 ± 3	6.9 ± 5	0.078
Weeds %		4.4 ± 7	6.3 ± 5	<0.001	5.1 ± 9	3.7 ± 4	0.6	5.7 ± 4	6.9 ± 6	0.6
Other %		15.7 ± 16	3.4 ± 9	<0.001	12.4 ± 15	19.1 ± 17	0.055	1.0 ± 2	5.4 ± 11	0.2
Dead matter %		14.0 ± 11	5.6 ± 3	<0.001	12.3 ± 11	15.7 ± 12	0.2	5.6 ± 3	5.6 ± 3	0.7
Perennial ryegrass %	Late spring	72.8 ± 10	81.2 ± 12	0.024	74.7 ± 8	70.9 ± 12	0.430	83.2 ± 4	79.5 ± 12	0.500
	Summer	30.9 ± 13	74.4 ± 11	<0.001	33.8 ± 15	28.0 ± 12	0.430	80.5 ± 5	69.4 ± 13	0.023
	Autumn	54.5 ± 22	82.4 ± 11	<0.001	56.2 ± 18	52.8 ± 27	0.780	86.7 ± 5	78.8 ± 13	0.110
	Early spring	76.5 ± 9	76.6 ± 13	0.988	78.9 ± 12	74.1 ± 6	0.280	80.9 ± 9	73.0 ± 16	0.320
White clover %	Late spring	6.3 ± 5	4.7 ± 3	0.230	8.4 ± 34	4.2 ± 5	0.082	4.2 ± 2	5.2 ± 3	0.440
	Summer	5.5 ± 4	9.2 ± 5	0.013	7.6 ± 5	3.7 ± 2	0.029	6.8 ± 3	11.1 ± 5	0.035
	Autumn	11.2 ± 9	3.6 ± 3	<0.001	14.0 ± 11	8.7 ± 7	0.220	2.6 ± 2	4.4 ± 3	0.110
	Early spring	5.8 ± 4	6.5 ± 4	0.607	7.1 ± 5	4.5 ± 3	0.160	5.7 ± 3	7.1 ± 5	0.450
Weeds %	Late spring	2.6 ± 2	6.7 ± 5	0.005	2.4 ± 2	2.8 ± 3	0.670	6.6 ± 5	6.7 ± 6	0.990
	Summer	4.6 ± 4	8.1 ± 4	0.010	3.8 ± 4	5.3 ± 5	0.530	7.4 ± 3	8.7 ± 4	0.430
	Autumn	7.3 ± 12	6.5 ± 5	0.780	11.0 ± 2	3.6 ± 3	0.240	4.4 ± 3	8.2 ± 7	0.140
	Early spring	3.3 ± 3	4.1 ± 4	0.450	3.8 ± 2	2.9 ± 3	0.490	4.3 ± 4	4.0 ± 4	0.830
Other %	Late spring	7.2 ± 6	2.3 ± 7	0.028	6.4 ± 6	7.9 ± 6	0.600	0.3 ± 0.7	3.9 ± 9	0.260
	Summer	34.0 ± 18	3.3 ± 9	<0.001	29.9 ± 21	38.2 ± 16	0.360	0.6 ± 1	5.6 ± 12	0.210
	Autumn	11.7 ± 14	2.2 ± 6	0.009	5.9 ± 8	17.5 ± 16	0.084	0.06 ± 0.2	4.0 ± 8	0.180
	Early spring	9.6 ± 8	5.9 ± 12	0.271	6.7 ± 3	12.6 ± 10	0.120	3.1 ± 3	8.2 ± 16	0.340
Dead matter %	Late spring	11.1 ± 6	5.2 ± 2	<0.001	8.1 ± 3	14.2 ± 7	0.030	5.6 ± 3	4.8 ± 2	0.410
	Summer	25.1 ± 14	5.0 ± 3	<0.001	24.9 ± 14	25.3 ± 14	0.96	4.7 ± 1	5.3 ± 4	0.68
	Autumn	15.3 ± 8	5.4 ± 4	<0.001	12.9 ± 7	18.0 ± 10	0.250	6.2 ± 4	4.7 ± 3	0.390
	Early spring	4.8 ± 4	6.9 ± 4	0.097	3.6 ± 2	6.0 ± 5	0.230	5.9 ± 2	7.7 ± 4	0.220

intervals lower herbage quality. Similarly, Bryant et al. (2014) reported that pastures generated from a shorter grazing interval (19 days) had a greater N content (by 16 g/kg DM), compared with pastures generated from a longer grazing interval (35 days).

The proportion of white clover and dead matter in pastures are likely to influence pasture CP content. This seems to have been the case in the Waikato in late spring with the lowest pasture CP content for the Low BMU group, which corresponded with greater dead matter in pasture (P=0.030) and a trend (P=0.082) for lower white clover content.

Conclusions

We determined that Low BMU farms tended to have a greater pre-grazing herbage mass and graze their pastures at a greater leaf stage, and they had longer intervals between grazing relative to High BMU farms. These differences in grazing management were consistent with a lower mean pasture CP content for the Low BMU farms, which is likely to have altered the N surplus in the herd's diet. Further work is required to determine the relative importance of these factors in relation to altering BMU, along with other farm management factors such as supplement and N fertiliser use.

Canterbury farms had a greater pre-grazing herbage mass, more advanced leaf stage, and longer grazing

Table 6 Mean crude protein (% of DM ± SD) and metabolisable energy (MJ ME/kg DM ± SD) content of pastures sampled on participating farms in Waikato and Canterbury across season during late spring, summer, autumn, and early spring.

Region	Visit	Historic bulk milk urea status High mean ± SD	Low mean ± SD	P-value
Overall group means for High and Low BMU				
Crude protein		22.5 ± 2.73	19.8 ± 3.20	<0.001
Metabolisable energy		11.2 ± 0.89	11.0 ± 1.17	0.804
Crude protein by region and visit				
Waikato	Late spring	22.3 ± 1.19	16.3 ± 2.29	<0.001
	Summer	18.3 ± 2.29	18.5 ± 3.41	0.882
	Autumn	24.2 ± 2.21	21.2 ± 3.16	0.05
	Early spring	24.5 ± 1.99	19.9 ± 3.41	0.001
Canterbury	Late spring	20.7 ± 1.35	19.1 ± 2.57	0.083
	Summer	22.7 ± 2.49	20.7 ± 2.42	0.086
	Autumn	24.3 ± 2.17	23.2 ± 1.78	0.252
	Early spring	22.9 ± 1.70	19.3 ± 2.27	0.001
Metabolisable energy by region and visit				
Waikato	Late spring	10.6 ± 0.38	9.8 ± 0.90	0.043
	Summer	9.6 ± 0.55	9.2 ± 1.24	0.384
	Autumn	11.0 ± 0.61	10.6 ± 1.17	0.424
	Early spring	12.0 ± 0.38	11.7 ± 0.45	0.115
Canterbury	Late spring	11.1 ± 0.45	11.1 ± 0.59	0.922
	Summer	11.2 ± 0.26	11.3 ± 0.40	0.622
	Autumn	11.6 ± 0.42	11.7 ± 0.44	0.837
	Early spring	12.2 ± 0.17	12.1 ± 0.50	0.849

intervals than Waikato farms. Many of the Waikato farms had pastures grazed at less than the recommended minimum 2-leaf stage for perennial ryegrass, especially in the spring months, which typically reduces the herbage mass (kg DM/ha) offered. Despite this, Waikato farms achieved adequate pre-grazing herbage mass in early and late spring, suggesting that N fertiliser responses had a role. The interaction between spring N fertiliser use, leaf stage, pre-grazing herbage mass, N content of pasture and BMU group requires further investigation in these case study farms.

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