Variation in kale and fodder beet yield and quality over winter affects nutrient supply to non-lactating dairy cows at the Southern Dairy Hub

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Abstract

Estimating crop quality and quantity is important for feed budgeting and nutritional balancing of diets for winter grazing. Commonly, farmers measure crop dry matter (DM) yield in autumn, but few complete quality tests. We assessed the DM yield and quality of late spring sown kale and fodder beet (FB) from early autumn to late winter over five years at the Southern Dairy Hub, Southland, New Zealand. Yield and quality parameters were analysed over time since sowing, using polynomial data fitting. We hypothesised that crop yields would remain stable during winter grazing, but that the supply of nutrients would vary, driven by a decline in the leaf proportion. Overall, crops showed rapid growth prior to winter but stable yields during winter grazing, but there was year to year variation in apparent growth trends and yields. The proportion of FB bulb increased over winter relative to the total crop yield for all cultivars and years. Fodder beet leaf was numerically higher in multiple nutrient concentrations (crude protein, Ca, Mg, P, S) compared to the bulb. For both crops, nutrients had only small fluctuations in concentration over time. Completing yield assessments in late autumn would give farmers a useful baseline yield indication for winter. Crop quality tests are recommended to identify any nutritional deficiencies that need addressing to ensure good animal health and performance.

Keywords: *Beta vulgaris L.*, *Brassica oleracea L.,* bulb, protein, Southland

Introduction

Dairy farming in Southland contributed 13% of total milk solids and had the third highest cow population in New Zealand in the 2021-22 milking season (LIC and DairyNZ, 2022). Fodder beet (FB; *Beta vulgaris L.*) and kale (*Brassica oleracea L.*) are commonly fed to dairy cattle in winter in Southland, to compensate for a feed deficit driven by low temperatures and pasture growth (Nichol et al. 2003).

Relative to pasture in winter, FB and kale provide high yielding, highly digestible feed, which supports body condition score (BCS) gain over this time. Fodder beet is low in tissue nitrogen (N) content, which has been shown to have environmental benefits, driven by a lower cow N intake causing a reduction in N leaching via urinary N pathways (Dalley et al. 2020b; Di and Cameron 2007). Kale in comparison is higher in N content but lower in dry matter (DM) yield (de Ruiter et al. 2015), and it has been reported that its quality does not deteriorate over winter compared with other feeds (Judson and Edwards 2008).

It is important for pregnant non-lactating cows to achieve BCS targets for calving. If cow requirements are not met, there is a risk of poorer performance post-calving (Edwards et al. 2020), as well as animal health issues such as ruminal acidosis, and negative effects on rumen function (Pacheco et al. 2020; Fleming et al. 2021). Pregnant, non-lactating cows require 12% crude protein (CP; % of DM) and heifer replacements require 14-17% CP in their diets (National Academies of Sciences, Engineering, and Medicine (NASEM) 2021); FB and kale are typically 9-14% CP and 12-18% CP respectively (DairyNZ 2020). Metabolisable energy (ME) requirements for pregnant non-lactating cows (500 kg LW) are 94 MJ/day (Nicol and Brookes 2007); FB and kale typically provide 12-12.5 and 11-13.5 MJ/kg DM respectively (DairyNZ 2020). Neutral detergent fibre (NDF; % of DM) requirements are >27-33%, which is higher than typical FB concentrations (14-20%), driven by the low NDF in the FB bulb (Clark et al. 1987). In comparison, kale NDF is 20-35% of DM (DairyNZ 2020). Phosphorus (P) requirements for non-lactating cows in late pregnancy are 0.19% and 0.21% for cows 60-21 days, and <21 days prepartum, respectively (NASEM 2021). Phosphorus concentrations in FB are typically below this level, driven by lower levels in the bulb (Dalley et al. 2021). In the absence of P supplementation, blood P concentrations can rapidly deplete (Dalley et al. 2021).

Commonly over winter, FB or kale can contribute 60% or more of the cow's diet (Edwards et al. 2020; Pacheco et al. 2020), with the FB bulb making up a large proportion of the whole crop DM, for example 80% or more reported in Dalley et al. (2020a). The FB bulb is lower in N, NDF, P and calcium (Ca) compared to the leaf (Waghorn et al. 2018). A decline in FB leaf

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percentage over winter has been reported by Dalley et al. (2020a), but there is limited literature on the change in the quality of the leaf and bulb over time. Changes in crop quality during winter may mean that supplementation with other types of feed and/or minerals is required to meet pregnant, non-lactating cow requirements.

Nutritional deficiencies associated with kale feeding are less common. However, Dalley et al. (2021) has reported that cows wintered on a kale diet had lower blood Ca than cows on FB. Research at the Southern Dairy Hub (SDH) also reported blood magnesium (Mg) levels in the lower end (0.75-0.8 mmol/l) of the normal range in cows grazing kale (Dalley 2018; Dalley et al. 2021). The kale leaf accounts for a higher proportion of the total DM (aboveground plant) compared to FB leaf. Energy and crude protein are highest in the kale leaf compared with the stem and both decline further down the stem (Judson and Edwards 2008). The average CP content of a winter diet containing 50% kale may not meet pregnant, non-lactating cow requirements if high quality supplements are not fed (Nichol et al. 2003). Lignification of the kale stem further reduces the quality (Judson and Edwards 2008), therefore the ratio of the stem and leaf over time may result in changes in the nutrient profile provided to cows.

Given the importance of wintering in the preparation of animals for the next milking season, it is important that farmers prepare accurate winter feed budgets to plan grazing management and estimate supplementary feed requirements. Commonly, farmers measure crops for yield in mid-to-late autumn to plan for the start of winter grazing. Most farmers have their crop yield measured commercially (including leaf and bulb separately for bulb crops), but some conduct their own assessments (Edwards et al. 2020). Whilst autumn measurement gives farmers a point in time yield, the future yield at grazing is harder to predict. Few farmers complete crop quality tests and so the nutrients being supplied are largely unknown. The nutrient profile of the leaf and bulb (or stem) are different, so changes in this ratio influence the diet. If farmers do test for quality, potential declines in the proportion of leaf over winter mean that it is difficult for them to predict nutrient supply changes without additional testing.

As part of a larger farm systems study at SDH, an opportunity arose to assess the DM yield and quality of late spring sown kale and FB from early autumn to late winter over five years. We hypothesised that crop yields would remain stable during winter grazing, but the supply of nutrients and minerals would vary due to changes in the proportion of leaf relative to the total crop. We also investigated whether winter yield for kale and FB could be reliably predicted from autumn yield assessments.

Materials and Methods

Experiment design and site

This study was part of an ongoing, wider farm system and winter-feeding experiment at SDH, a 349-ha research dairy farm (Southland, NZ 46°18’37.8” S, 168°18’46.1” E, 11 m a.s.l.). As this study was conducted as an exploratory opportunity and not as a planned experiment, it was not designed with rigorous statistical protocols, and as such, descriptive observations were made but statistical tests were not conducted. Therefore, the results and conclusions should be treated with these limitations in mind.

Crop establishment information, crop yield, crop quality, and climate data were collated between spring 2017 and the end of winter 2022 from farm records to analyse FB and kale yield and quality over five winters from 2018 to 2022. The year (2018 to 2022) refers to the year in which winter grazing occurred and crop establishment information related to the spring prior (2017 to 2021).

The farm winters 740 cows on-farm on either kale or FB. Crops were grown as part of the pasture renewal program in the following crop rotations: pasture → FB → FB→ new pasture or pasture → kale → kale→ new pasture. Crop paddocks were 3 ha each. Crops were grown across the whole effective area of the farm until 2020 when there was a flood event on the lower terrace (Pukemutu soil; silt loam, poorly drained; Manaaki Whenua 2019). As a result, subsequent crops were exclusively grown on the upper terrace (Waikiwi soil; silt loam, well drained; Manaaki Whenua 2019) from spring 2021. Data from 43 individual kale crops and 39 individual FB crops were collated (Table 1). Cultivars were selected by availability of seed at sowing.

Crop management and allocation

All seed was sourced from PGG Wrightson Seeds (PGW Seeds), Lincoln, NZ. Fodder beet was precision sown annually at a rate of 80,000 seeds/ha between 25 October and 4 December. Kale was sown annually at a seed rate of 4 kg/ha between 28 October and 10 December. All FB crop paddocks were conventionally cultivated (ploughed, aerated, power harrowed, levelled) before sowing. Kale paddocks were prepared via minimum tillage during 2018 and 2019. In 2020, half of a paddock was prepared via minimum tillage and the other half direct drilled. All remaining paddocks were sown by direct drilling in 2020. Kale was sown via direct drilling only in 2021. First year crop paddocks were sprayed out with applications of Glyphosate (Roundup®; 4 L/ha), Hammer®Force (100 mL/ha) and Li-1000® (500 mL/ha) 2 to 3 weeks before establishment of crops. Fertiliser and chemicals applied were based on recommendations from the farms’

Table 1 Number of paddocks by cultivar between 2018-2022 (winter grazing year)

Crop	Cultivar	2018	2019	2020	2021	2022
Kale	Firefly[1]			10	13	
	Kestrel[2]	2				
	Regal[1]	7	10	1		
Fodder beet	Brunium and Jamon[3]				3	
	Feldherr			9		
	Jamon	9	9		6	3

[1] Regal and Firefly, intermediate height

[2] Kestrel, short marrow-stem height

[3] Mixed seed

agronomy representative (PGW Seeds technical team, pers. comm.).

For the FB diet, the target feed allocation was 9.5 kg DM/cow/day with 3.5 kg DM/cow/day of baleage offered. For the kale diet the target feed allocation was 11 kg DM/cow/day and 3.5 kg DM/cow/day of baleage offered. Crop area allocation was determined from fortnightly yield assessments and crop type. Cows were supplemented with 50 g/cow/day dicalcium phosphate (DCP) when grazing FB.

Sampling and analysis

Fodder beet samples were collected between 1 March and 13 September and kale samples were collected between 1 March and 16 August, depending on the year. Crop DM yield was assessed both before and during winter grazing. Crop quality analyses were conducted during winter grazing only. Samples taken for yield assessment before grazing were collected monthly and were representative of all crop paddocks and the whole paddock area. Samples taken for yield and quality assessment during winter grazing were collected fortnightly and represented the portion of the paddock scheduled to be grazed during the next two weeks. The number of paddocks and therefore samples collected declined over winter as the area available declined as crops were grazed.

In each kale paddock, aboveground yield was measured by taking three 1 m^2 quadrats (1 quadrat per ha). Kale plants from each quadrat were cut to ground level and weighed fresh. Representative plants (minimum of two whole plants per quadrat) were sub-sampled for DM% and forage quality analysis. Kale leaf and stem were not separated for analysis. Fodder beet whole plant yield was assessed from three 4 m long double rows of crop. Fodder beet plants were harvested, soil removed, and the fresh weight of the leaf (plus stem) and bulb recorded separately. Subsamples of bulb and leaf (minimum of four whole plants per paddock) were collected for DM% and forage quality analysis.

Crop samples were sent fresh to Hill Laboratories (Hamilton, New Zealand) where sample preparation and analysis was conducted. In brief, samples were dried at 62°C overnight and ground to 1 mm before being analysed. The DM content of kale and FB were determined by drying samples at 95°C until a stable weight was achieved (up to 48 hours). Feed quality parameters: N, CP, acid detergent fibre (ADF), NDF, digestibility of organic matter in dry matter (DOMD), soluble sugars, and ash, were estimated using near infrared spectroscopy (MPA FT-NIR Analyzer, Bruker Optics, Billericia, MA). Organic matter % was calculated as 100 – ash %. Metabolisable energy was derived from DOMD using the following calculation: ME = 0.16 × DOMD. The minerals P, potassium (K), sulphur (S), Ca, Mg, and sodium (Na) were analysed by ICP-OES (iCAP^{TM} 6500 or iCAP^{TM} 7400, ThermoFisher Scientific, Waltham, MA USA) following nitric acid/hydrogen peroxide digestion.

Climate measurements

Seasonal climate data for each year are summarised in Table 2 for contextual purposes. An analysis of climatic factors in relation to crop growth was not conducted. Rainfall, air temperature, soil temperature, sunshine hours, and potential evapotranspiration (PET) were recorded at SDH every 15 minutes by a weather-monitoring system (HALO Systems, Hamilton, New Zealand). Records were reported as daily totals for rainfall (mm); minimum, average, and maximum air temperature (°C); average soil temperature (°C); total PET (mm); and total sunshine hours.

Statistical analysis

Two severely flood affected FB paddocks from the 2020 year were removed from the analysis. Fitted polynomials (with 95% confidence bands) were used to visualise trends in DM yield and quality over time, including the proportion of bulb and leaf for FB. All analyses were conducted using R version 4.2.2. (R Core

Table 2 Summary seasonal climate data of each year 2018-2022. Rain (mm) is cumulative rainfall for the season, sunshine (hrs) is the mean of daily sunshine hours for the season, air and soil temperatures (°C) are the mean of daily temperatures for the season.

Season		2018	2019	2020	2021	2022
Spring	Rain (mm)	190	283	317	383	280
(1 Sep to 30 Nov)	Sunshine (hrs)	6.4	6.0	5.6	6.0	5.7
	Temperature air (°C)	11	10.4	10.3	10.6	11
	Temperature soil (°C)	9.9	9.2	9.0	9.4	9.9
Summer	Rain (mm)	222	249	290	280	162
(1 Dec to 28 Feb)	Sunshine (hrs)	6.9	6.9	6.2	6.2	7.3
	Temperature air (°C)	16.0	15.2	14.2	14.1	14.4
	Temperature soil (°C)	15.8	14.6	13.6	13.8	14.6
Autumn	Rain (mm)	382	269	198	276	268
(1 Mar to 31 May)	Sunshine (hrs)	3.9	4.6	4.3	4.3	4.8
	Temperature air (°C)	10.8	12.0	10.7	10.7	12.2
	Temperature soil (°C)	9.8	10.6	9.3	9.6	10.7
Winter	Rain (mm)	229	307	259	304	260
(1 June to 31 Aug)	Sunshine (hrs)	3.5	3.2	3.3	3.2	3.7
	Temperature air (°C)	6.6	7.0	6.7	7.1	6.5
	Temperature soil (°C)	4.7	5.5	5.1	5.4	4.9

Team 2023) and the ggplot2 package (Wickham 2016). Dry matter yield and crop quality data were presented as means per paddock and time point. Yield dates were standardised to 'days since sowing', with day 0 being the sowing date. Day '0' represented a spread of 40 days for FB (25 October to 4 December) and 43 days for kale (28 October to 10 December).

To investigate whether winter yields for FB and kale could be reliably predicted from autumn yield assessments, several linear mixed models were tested. These models used autumn yield, autumn and winter growing days, cultivar, soil type and autumn soil water deficit as predictors.

Results

Crop yields

During winter grazing, mean FB yields in May ranged from 16.3 t DM/ha (2020) to 23.9 t DM/ha (2018). In June, yields ranged from 15.1 t DM/ha (2020) to 22.5 t DM/ha (2022) and in July ranged from 15.8 t DM/ha (2020) to 23.0 t DM/ha (2019). There was high variation in yields both within and between paddocks. For all years combined, the relationship between FB yield and days since sowing visually showed rapid growth between 100 and 200 days since sowing and a stable yield after 200 days.

However, there was variability in FB yields when split by year (Figure 1). For 2019 and 2021, yields peaked later at 225-250 days since sowing. In 2022, FB peak yield (23 t DM/ha) was achieved by 170 days since sowing and in 2018, FB peak yield (22.6 t DM/ha) was achieved by 200 days. For all years except 2020, FB yields visually declined towards the end of winter. Flooding events in February 2020 potentially impacted the remaining FB crop paddocks.

The proportion of FB bulb in the total crop harvest numerically increased over time, which was consistent across all cultivars and years (Figure 2). The increase in the proportion of bulb during the whole measurement period (100 to 300 days since sowing) ranged from 16% to 25%. The increase in FB bulb proportion between 100 to 175 days since sowing (before winter grazing) was 7% to 16%, compared to 175 to 225 since sowing (2% to 6%). Between 225 to 300 days since sowing there was little change in the proportion of bulb.

Kale yields in May ranged from 11.5 t DM/ha (2018) to 13.6 t DM/ha (2019). In June, yields ranged from 10.6 t DM/ha (2020) to 13.5 t DM/ha (2021) and in July ranged from 11.0 t DM/ha (2021) to 14.9 t DM/ha (2019). For all years combined, the relationship between kale DM yield and days since sowing visually showed rapid growth between 100 to 160 days and a relatively stable DM yield after 160 days. In 2019, yields peaked at 200 days since sowing, and in 2021 yields peaked at approximately 175 days (Figure 3). In 2018, yield visually increased from 100 days since sowing to the end of sampling. For all years except 2018, kale DM yields appeared to decline towards the end of winter.

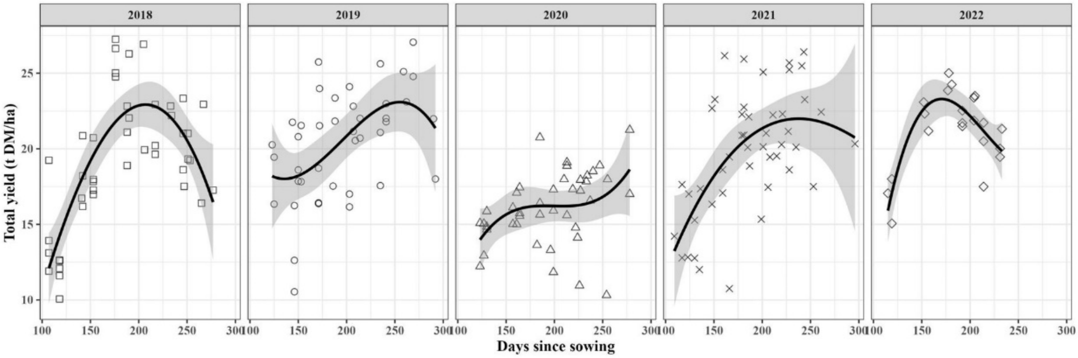

Figure 1 Relationship between mean FB yield (t DM/ha) and days since sowing for each measurement year 2018-2022 for all cultivars. Grey shaded area is the 95% confidence interval for a third-degree polynomial smooth using lm (linear model) in ggplot2 (Wickham 2016).

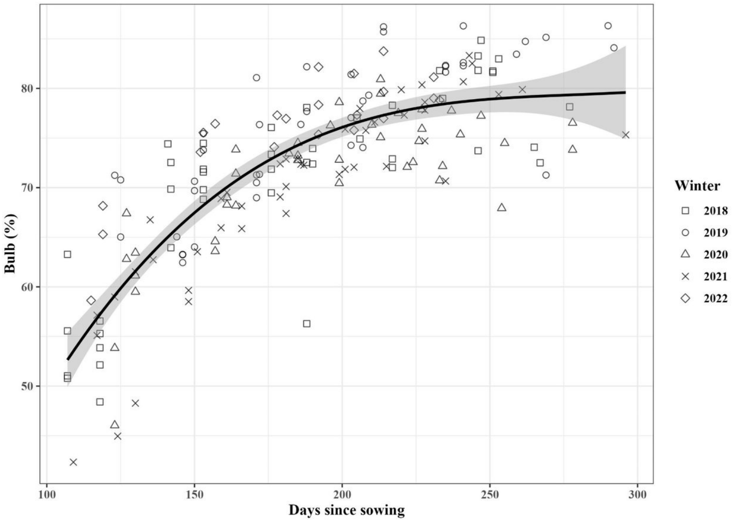

Figure 2 Relationship between FB bulb (% of total crop mass) and days since sowing for 2018-2022 (combined data for all cultivars). Grey shaded area is the 95% confidence interval for a third-degree polynomial smooth using lm (linear model) in ggplot2 (Wickham 2016).

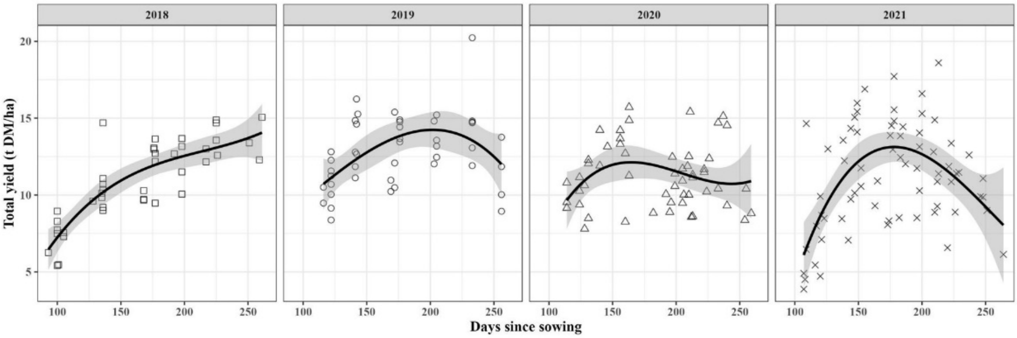

Figure 3 Relationship between mean kale yield (t DM/ha) and days since sowing for each measurement year 2018-2021 for all cultivars. Grey shaded area is the 95% confidence interval for a third-degree polynomial smooth using lm in ggplot2 (Wickham 2016).

Table 3 Mean (± SD) quality data for whole plant fodder beet and kale for 2018 to 2022 for all cultivars during the winter grazing period. SD is standard deviation.

Fodder beet	**2018**	**2019**	**2020**	**2021**	**2022**
Dry matter (%)	15.1 (0.15)	15.8 (1.1)	14.0 (0.7)	16.0 (1.1)	16.6 (0.02)
Crude protein (% of DM)	13.2 (1.2)	11.2 (0.5)	11.7 (1.7)	10.9 (1.3)	10.4 (1.2)
Metabolisable energy (MJ/kg DM)	13.8 (0.3)	13.9 (0.3)	13.7 (0.3)	14.1 (0.3)	12.5 (0.04)
Phosphorus (% of DM)	0.17 (0.01)	0.17 (0.03)	0.21 (0.03)	0.16 (0.02)	0.13 (0.01)
Magnesium (% of DM)	0.22 (0.03)	0.24 (0.04)	0.25 (0.03)	0.23 (0.04)	0.24 (0)
Calcium (% of DM)	0.30 (0.08)	0.29 (0.04)	0.27 (0.02)	0.30 (0.09)	0.33 (0.04)
Sulphur (% of DM)	0.12 (0.01)	0.11 (0.01)	0.12 (0.02)	0.11 (0.02)	0.11 (0.01)
Neutral detergent fibre (% of DM)	16.8 (2.7)	14.8 (1.4)	16.2 (2.5)	13.8 (1.3)	13.9 (0.05)
Total sugars (% of DM)	44.0 (8.8)	55.7 (3.9)	50.8 (4.8)	57.4 (3.6)	55.2 (1.2)
Kale	**2018**	**2019**	**2020**	**2021**	
Dry matter (%)	12.9 (1.4)	11.8 (1.6)	11.7 (1.3)	11.6 (1.8)	
Crude protein (% of DM)	16.2 (2.7)	14.5 (2.9)	17.1 (5.0)	18.0 (3.8)	
Metabolisable energy (MJ/kg DM)	12.1 (0.6)	11.5 (0.7)	12.3 (0.8)	12.5 (0.4)	
Phosphorus (% of DM)	0.27 (0.05)	0.27 (0.02)	0.33 (0.05)	0.30 (0.05)	
Magnesium (% of DM)	0.16 (0.01)	0.18 (0.03)	0.18 (0.03)	0.18 (0.03)	
Calcium (% of DM)	1.17 (0.20)	1.15 (0.27)	1.32 (0.28)	1.13 (0.16)	
Sulphur (% of DM)	0.59 (0.10)	0.67 (0.15)	0.69 (0.17)	0.67 (0.13)	
Neutral detergent fibre (% of DM)	25.2 (3.7)	29.3 (5.2)	24.0 (4.6)	23.4 (2.3)	
Total sugars (% of DM)	25.2 (4.6)	23.2 (4.6)	22.2 (7.0)	23.8 (4.2)	

Total annual rainfall ranged from 991 mm (2022) to 1247 mm (2021). The highest total rainfall per season was in spring 2021 (383 mm), followed by autumn 2018 (382 mm). Mean air and soil temperatures were similar across the years within each season. Total sunshine hours were highest in summer and lowest in autumn.

Crop quality

Summary feed quality data for FB and kale for selected nutrients are presented in Table 3. There were apparent differences between the crops and years in several nutrients, however these were not tested statistically. Mean DM and ME content ranged from 14.0 to 16.6% and 12.5 to 14.1 MJ/kg DM respectively for FB, whereas kale DM ranged from 11.6 to 12.9% and ME ranged from 11.5 to 12.5 MJ/kg DM. Mean FB CP content (% of DM) ranged from 10.4 to 13.2% in 2022 and 2018 respectively. In comparison, mean kale CP content (% of DM) ranged from 14.5 and 18.0% in 2019 and 2021 respectively. Mean P content (% of DM) in FB ranged from 0.13 to 0.21% across the years, compared to kale (0.27 to 0.33%). Mean S content (% of DM) ranged from 0.59 to 0.69% in kale, compared to 0.11 to 0.12% in FB.

Fodder beet quality trends over time in Figure 4 show that crop nutrient concentration appeared to be stable over time for most nutrients. However, there were visual differences in the concentrations of nutrients in the FB bulb compared to the leaf. Given that the nutritional quality values from bulb and leaf do not overlap on the plot, it is clear that significant differences exist between the tissue components and removes the need for formal statistical tests to establish the presence of a difference. Crude protein in the FB leaf ranged from 17.1 to 25.3%, compared to the bulb that ranged from 7.2 to 11.5%. There appeared to be changes in some quality measurements over time, however these were not tested statistically. The FB leaf appeared higher in Ca, Mg, P, S and NDF compared to the bulb, but the bulb was numerically higher in DM and ME during the measurement period. The concentration of total sugars, S, ME, and NDF over winter appeared relatively stable for both the leaf and bulb.

Kale quality measurements are presented in Figure 5. The concentrations of Ca, CP, Mg, DM and S appeared to be relatively stable over the winter grazing period. There appeared to be changes in some quality measurements, such as a decline in ME and an increase in NDF, however these were not tested statistically.

Yield predictions

Several mixed models were tested to predict FB and kale yields in winter from yields in autumn. However, all models had low predictive power, reflecting the fact that FB and kale yields were similar between autumn and the grazing period irrespective of harvest date and year.

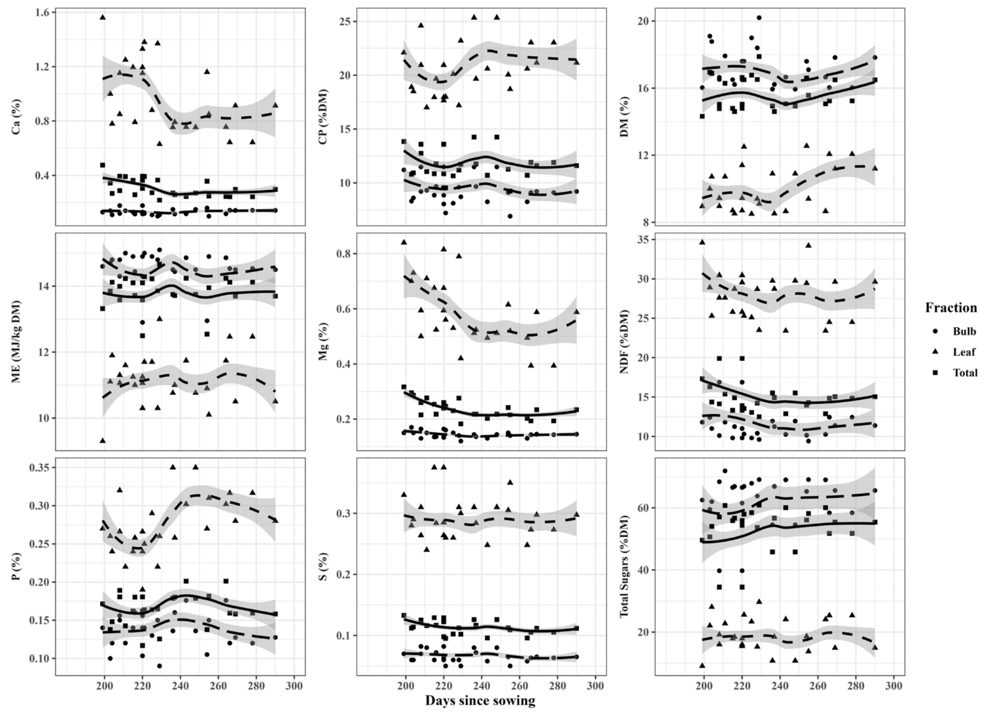

Figure 4 Nutritional quality of fodder beet bulb, leaf and whole crop between 200-300 days since sowing for the Jamon cultivar for 2018, 2019, 2021 and 2022. Grey shaded area is the 95% confidence interval for a LOESS smooth in ggplot2 (Wickham 2016).

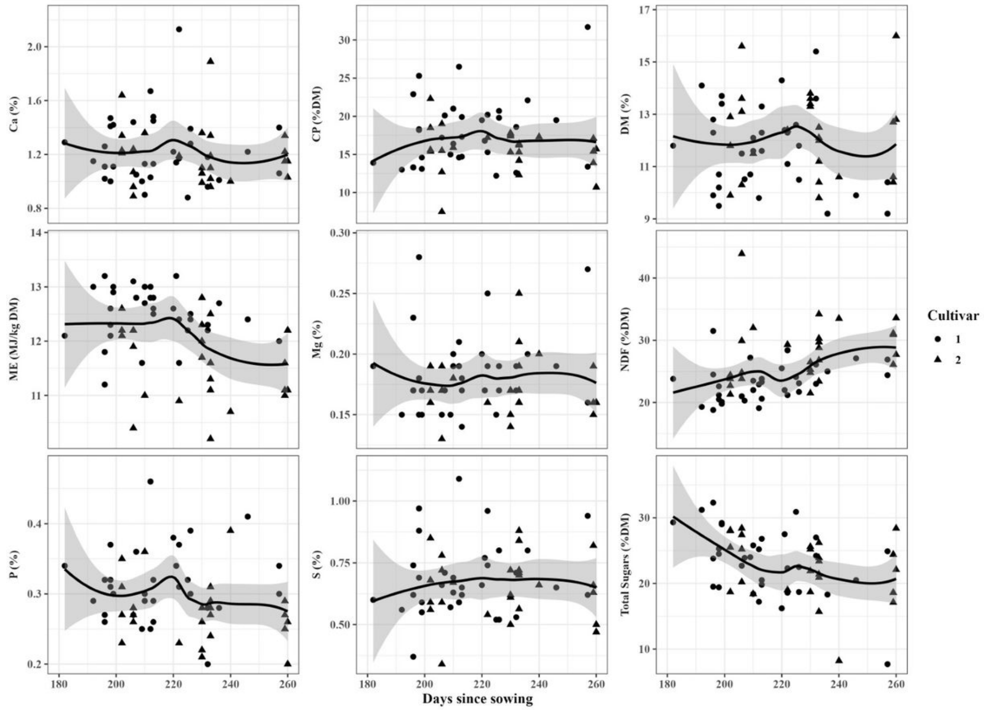

Figure 5 Nutritional quality of kale (whole crop) between 180-300 days since sowing for Regal (▲) and Firefly (●) cultivars for 2018, 2019, 2020 and 2021. Grey shaded area is the 95% confidence interval for a LOESS smooth in ggplot2 (Wickham 2016).

Discussion

This study assessed the yield and quality of FB and kale before and during winter grazing. As this study was exploratory in nature, and not designed with rigorous statistical protocols, the results are of a descriptive nature without statistical tests and therefore, results and conclusions should be treated with these limitations in mind. We hypothesised that crop yields would remain stable during winter grazing, which was supported by our findings when considering all years combined. We observed stable FB and kale yields except for a slight decline at the end of winter. However, there was year to year variability in this relationship and differences in the timing of peak yields. Our expectation that the total crop concentrations of nutrients and minerals would vary due to changes in the proportion of leaf relative to the total crop was not apparent. For FB, our results showed a consistent decline in FB leaf over the five winters, but this decline had a negligible impact on nutrient supply due to the large contribution of bulb DM to the diet. For kale, we did not measure the changes in the proportion of leaf compared to stem, but the concentration of nutrients from the whole crop over time appeared relatively stable. While this was the case at SDH in this study, this may not apply in other environments such as at higher altitudes and colder temperatures, where there may be less thermal time for leaf production and increased risk of leaf loss, thus reducing DM yield potential (Brown et al. 2007).

Fodder beet and kale yields observed during this period were consistent with expected yields in Southland, except for those paddocks affected by flooding in 2020. Brunium and Jamon FB cultivars are advertised as having potential yields of 18-22 t DM/ha and a 16-18% bulb DM content (Agricom Ltd 2020), which were similar to ranges found in this study. Conversely, observed peak kale yields were between 13.0 to 14.9 t DM/ha, which were lower than the 16 t DM/ha advertised potential reported for Regal, Kestrel and Firefly cultivars (PGG Wrightson Seeds, 2022).

There was high variation in yields across paddocks, years, and cultivars, likely caused by multiple factors such as sampling site within the paddock, sowing date, climate, soil type, emergence success, weed and pest control, and fertiliser (Judson et al. 2016). Despite this variation, DM yield mostly reached a plateau during the key winter grazing period which supports results from Dalley at al. (2020a) and Fraser et al. (2001). It is however important to note an end of winter decline in yield in some years. With the limited literature available, we attribute this to a combination of the decline in leaf dry matter yield and/or the advancing maturity of the bulb or stem becoming senescent. Low light levels in winter may restrict growth and promote senescence like that reported in pasture (Wall et al. 2012). Our results indicate that taking yield assessments in late autumn may give farmers a useful baseline yield indication for winter, given that DM yields remained mostly stable during the key winter grazing period, but that there will be seasonal variability. Farmers assessing yield after approximately 200 days and 160 days since sowing for FB and kale respectively, can expect a similar yield by the start of winter grazing and little change thereafter.

Our results showed a numerical decline in FB leaf over winter across all cultivars and years as the FB bulb proportion increased. This aligns to similar findings by Dalley et al. (2020a) who reported an increase in FB bulb proportion from 72% in June to 82% by mid-August. Despite this decline, there was a negligible impact on overall nutrient supply, because the bulb DM contributed a large portion of the diet throughout winter, and nutrients from the leaf became a smaller portion of the total nutrients over time. Most nutrients appeared to only have small fluctuations over time and thus the concentrations were relatively stable.

The leaf and stem of kale were not analysed separately, so we cannot comment on changes in the proportion of leaf during winter. However, like FB, the concentration of nutrients in the whole crop over time was also relatively stable. Previous research has found that the proportion of leaf is related to total DM yield, and leaf declines by 3% for every extra tonne of DM grown (Judson and Edwards 2008). We observed both an increase in kale NDF over winter which may indicate lignification of the stem (Westwood et al. 2014), and a decline in ME, which may be linked to the poorer quality stem (Judson and Edwards 2008).

Despite a relatively constant forage quality from whole crop FB and kale, there were still obvious differences in the FB leaf compared to bulb nutrient concentrations. This reinforces the importance of knowing the leaf to bulb ratio of the crop and having these tested for nutrient content so that any deficiencies are identified and addressed with supplements. At this site, strategies to maintain leaf DM through winter are unlikely to correct nutrient deficiencies in FB diets associated with low concentrations of key nutrients in the FB bulb. Maintaining FB leaf DM may also come at a cost, such as requiring fungicide sprays to reduce leaf decay. Further, a high proportion of FB in winter diets for dairy cattle is likely to exacerbate known mineral deficiencies in the absence of mineral supplementation (Waghorn et al. 2018). The target winter allocation of FB in this study was as high as 73%, which is more than recommended levels of no more than 60% of DM intake with silage for non-lactating cows, from a study by Pacheco et al. (2020). Quality results indicated that FB had lower levels of P, S, Ca and NDF than kale, in agreement with findings from Dalley et al. (2020a). Phosphorus levels in FB were numerically lower than the recommended levels over winter (NASEM 2021) which is similar to previous findings (Dalley et al. 2021). These observations reinforce the need for P supplementation when feeding FB to pregnant, non-lactating cows over winter.

Total sugars were numerically higher in FB than kale, and highest in the FB bulb. High levels of carbohydrates have been shown to lower ruminal pH through an increased production rate of lactic acid and volatile fatty acids (Darwin et al. 2018), and consequently increase the risk of ruminal acidosis when feeding FB. Crude protein content remained stable in kale over winter, which contrasts with a decline reported by Fraser et al. (2001). This may indicate that there was little decline in kale leaf proportion over time in this study. Relatively stable concentrations of multiple nutrients over winter meant that kale was more aligned to animal requirements and did not contribute the same deficiencies as feeding FB. However, in other situations, feeding kale to cattle may lead to deficiencies in other nutrients such as copper (Grace et al. 2010), highlighting the need for farmers to carry out crop quality tests regardless of the crop type.

Climate (long term) and weather (short term) factors affect the successful establishment and yield of kale and FB. Crops grew rapidly between 100-200 (FB) and 100-160 (kale) days since sowing. Sowing dates were standardised in this study, but there was a 43-day date range between establishment of the first and last crop in any given year, which could result in seeds and crops exposed to significantly different air and soil temperatures. For example, soil temperatures for crops grown in mid-spring (8.9 to 9.9°C) were lower than those sown early December (13.6 to 15.8°C). A study by Khaembah et al. (2019) showed that maximum growth rate and DM yield of FB was not affected by sowing date, meaning little advantage of early sowing because cold temperatures slowed canopy development. In contrast, early sowing of kale (November) increased the pre grazing DM yield, but this also led to lower N content in a study by Cheng et al. (2018).

In this study, we also investigated whether winter yield for kale and FB could be predicted from autumn yield assessments which could be used to estimate the potential range in DM available in winter for feed budgeting purposes. We concluded that FB and kale yields were similar between autumn and the grazing period irrespective of harvest date and year, resulting in models with low predictive power. Further investigation into the factors required to develop practical and useful prediction models is required.

Conclusions

Estimating feed quality and quantity is important for feed planning and ensuring that animals are offered sufficient nutrients to meet their requirements during the winter grazing period. Our multi-year single site results indicated stable FB and kale yields and stable whole plant feed quality during winter grazing. This was despite differences in the relative quality of the FB bulb and leaf, and changes in the proportion of these over time. Our results indicated that taking yield assessments in late autumn would give farmers a useful baseline yield indication for winter, given that DM yields remained mostly stable during the key winter grazing period. We also recommend that farmers carry out crop quality tests in late autumn to identify any nutritional deficiencies that need addressing to ensure good animal health and performance.

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