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RESEARCH NOTE

The effect of kale cultivar and sowing date on dry matter intake, crop utilization, liveweight gain and body condition score gain of pregnant, non-lactating dry dairy cows in winter in New Zealand

Short title: Utilization of kale by dry cows

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Abstract

An outdoor grazing study on kale was conducted with pregnant, non-lactating (dry) dairy cows over a 42-day winter grazing period commencing 9 June 2008. Kale treatments consisted of two kale cultivars varying in leaf:stem proportion ('Regal', a leafy variety and 'Caledonian', a stemmy variety) and two sowing dates (8 November and 15 December). Measurements were made for dry matter (DM) utilization, apparent DM intake, liveweight gain, and changes in body condition score (BCS) for a total of 120 cows allocated to three replicate groups of the four factorial treatments. Cows were offered a daily allowance of 10 kg DM/cow of kale and 2.2 kg DM/cow of straw. Pre-grazing DM yield was higher for kale sown in November (16517 kg DM/ha) than December (13867 kg DM/ha), but was unaffected by cultivar (average 15192 kg DM/ha). 'Regal' kale had a higher percentage of leaf compared to 'Caledonian' (33.6 *vs* 25.6 %), lower content of NDF (32.4 *vs* 34.1 %), but similar metabolizable energy content (12.1 MJ/kg DM for both) in the whole plant. Despite the differences in pre-grazing DM yield and forage quality among treatments, no differences were found in DM utilization (between 88.5 and 90.2 %), apparent DM intake (between 9.4 and 9.6 kg DM/cow.day), liveweight gain (between 0.53 and 0.67 kg/cow.day), and BCS gain (between 0.43 and 0.46 unit/cow over 42 days). Manipulation of kale yield and quality through choice of cultivar and sowing date had no effect on the performance of pregnant, non-lactating dairy cows.

Keywords: brassica, utilization, metabolisable energy, leaf and stem ratio, winter forage

1. INTRODUCTION

In New Zealand (NZ), dairy cow production is often managed under a spring calving system. Farmers generally aim to dry-off their pregnant cows at a body condition score (BCS) of 4.5 (1-10 NZ scale; Roche *et al.*, 2009) in autumn and allow the animals to gain 0.5 BCS unit during a six-week period by feeding winter forage. Brassica crops are increasingly used to feed dairy cattle in the autumn/winter period in NZ to fill the pasture feed gap (Cheng *et al.*, 2016; Rogoho *et al.*, 2010). Kale (*Brassica oleracaea* L.) is a common autumn/winter brassica forage offered to dry cows in southern NZ (Greenwood *et al.*, 2011). Kale produces a high standing dry matter (DM) yield and nutritional value appropriate for animal condition gain, when other winter forage species such as annual or perennial ryegrass (*Lolium multiflorum and L. perenne* L.) are in short supply (Brown *et al.*, 2007; Gowers & Armstrong 1994). Traditionally, kale is sown between October and December in NZ to allow at least five months growth before it is strip harvested/grazed by dry cows. Early sowing of kale generally results in a higher DM yield, due to increased exposure to thermal duration and accumulated solar radiation (Brown *et al.*, 2007; Wilson *et al.*, 2004). However, the earlier sowing may mean the crop is more mature when it is grazed by dry cows and thus have a reduced quality (Fraser *et al.*, 2001) and potentially lower dry cow performance. The potential kale yield and quality trade off from early sowing may be offset by selection of kale varieties with higher leaf to stem ratio, and with leaves being more digestible with more crude protein than in the stems (Judson & Edwards 2008, Rugoho *et al.*, 2010). There have been few published studies on the effect of different kale cultivars and different sowing dates on yield and quality, and on dry cow performance. Therefore, the objective of this study was to investigate the yield and quality difference between sowing date and cultivar treatments of kale, and to examine the utilization by grazing animals, liveweight (LW) gain and BCS gain responses over the winter grazing period.

2. MATERIALS AND METHODS

2.1 Experimental design and site management

This study was undertaken at Lincoln University Field Service Centre, Canterbury, NZ (43^{o}38'S, 172^{o}27'E; 15 m.a.s.l), under approval from the Lincoln University Animal Ethics Committee. The soil at the experimental site is Wakanui silt loam (recent yellow earth, gleyed). The trial was a randomized complete block design (12 plots) with two cultivars (leafy 'Regal' (LR) and stemmy 'Caledonian'(SC)) and two sowing dates (8 November 2007 (NOV) and 15 December 2007 (DEC)), replicated three times. Plots 1 - 4 consisted of two 15 m × 125 m strips/plot; plots 5 - 12 were one 15 m × 175 m and one 15 m × 87.5 m strip/plot. The site was prepared by conventional ploughing and rolling (Dutch harrow). Fertilization was as follows: 760 kg/ha of super-phosphate (9% P, 11% S and 20% Ca) was applied prior to sowing to all plots on 5 November 2007. Nitrogen fertilizer (urea) was applied to early sown plots on 5 November 2007 (50 kg N/ha), 22 January 2008 (50 kg N/ha) and 27 February 2008 (50 kg N/ha), and to late sown plots on 22 January 2008 (50 kg N/ha) and 27 February 2008 (50 kg N/ha). Kale was sown using a Fiona Drill in 15 cm rows at 4 kg/ha. All plots were irrigated in a single monthly application of 25 mm (11 November 2007 to the following year 28 March 2008) using a travelling irrigator. Monthly rainfall was consistent over this period at 55 ± 5 mm per month (Broadfields meteorological station, Lincoln, Canterbury, NZ).

2.2 Pre-grazing measurements

Pre-grazing yield of kale was measured by cutting to ground level. Three randomly positioned 1 m^2 quadrats per plot were taken at weekly intervals between 9 June and 14 July 2008 during grazing. Total quadrat fresh weight (FW) was measured in the field, and a sub-sample of three random plants from each quadrat were processed for leaf and stem FW, then oven-dried at 65 ˚C to a constant weight to calculate DM% and the leaf to stem ratio (DW basis). Leaf and stem samples were ground and scanned for quality by near-infrared spectroscopy (NIRS; Model: FOSS NIRSystems 5000, Maryland, USA). The NIRS calibrations for nitrogen (Variomax CN Analyser; Elementar), water soluble carbohydrates (WSC; MAFF, 1986), neutral detergent fibre (NDF; van Soest, 1991), and *in vitro* digestible organic matter content (Jones and Hayward, 1975) were derived from historical kale wet chemistry and NIRS calibration. R-squares for predictions were 0.98, 0.98, 0.99, and 0.97, respectively indicating a high level of accuracy. Metabolizable energy (ME) was calculated: ME (MJ/kg DM) = NIRS digestible organic matter content (g/kg DM) × 0.016 (McDonald *et al.*, 2011).

At the 30 June 2008 sampling, a sub-sample of one plant from each quadrat was separated into leaf and stem. The stem was then cut into four equal sections from the top to the bottom. The fractions were oven-dried at 65 ˚C to a constant weight to determine DM% before grinding and prediction of quality by NIRS.

2.3 Post-grazing measurements

The sampling method for post-grazing yield (9 June and 14 July 2008) was the same as for pre-grazing sampling, except that measurements were taken three times per week and the number of quadrats increased to three per plot. All plant material was recovered including the residual leaf and stem fractions on the soil surface and embedded in soil to a depth of 10 cm. Excess soil was washed from plant material and quadrat plant fresh weight was recorded then oven-dried at 65˚C to a constant weight to determine DM %.

2.4 Kale yield calculation, dry cow management and measurements

On 2 June 2008, 120 dry cows were blocked according to their BCS (4.44 ± 0.14; 0-10 NZ scale) and LW (549 ± 46 kg), and then randomly assigned to one of the 12 plots (10 cows per plot). In order to avoid risk of nitrate poisoning, all dry cows were adapted gradually to the kale over a period of seven days (2 June to 8 June 2008), with full allocation given on 9 June. At 08:00 h daily, all dry cows were offered 2.2 kg DM/cow/day straw at 7 MJ ME/kg DM and 0.8% nitrogen (on DM basis) as determined by NIRS. Utilization of straw was assumed to be 90%. Kale was offered in a single daily break at 09:00 h with a target intake of 10 kg DM/cow/day achieved by daily adjustment of break width according to prior DM yield assessment. Each plot was allocated over a 14.5 m face length with break widths of 4.6 ± 0.91 m, 5.2 ± 0.69 m, 4.9 ± 0.88 m, and 6.0 ± 0.95 m for the respective dietary treatment SC+NOV, SC+DEC, LR+NOV, and LR+DEC, respectively. Daily kale break width for each plot was determined by daily kale allowance, DM yield of kale measured from the previous week, and an assumption of 75% kale utilization. The following equations were then used to calculate DM yield, DM utilization, and apparent DM intake:

Pre-grazing DM yield (kg DM/ha) = average pre-grazing DM yield per 1 m^2 quadrat (kg DM/m^2) × 10000 (m^2/ha)

Post-grazing residual DM yield (kg DM/ha) = average post-grazing DM yield per 1 m^2 quadrat (kg DM/m^2) × 10000 (m^2/ha)

Kale DM utilization (%) = [pre-grazing DM yield (kg DM/ha) - post-grazing DM yield (kg DM/ha)] ÷ pre-grazing DM yield (kg DM/ha) × 100

Apparent DM intake (aDMI; kg/cow.day) of kale = [pre-grazing DM yield (kg DM/ha) - post-grazing DM yield (kg DM/ha)] per 1 m^2 quadrate (kg DM/m^2) × break width (m/day) × break length (m/day) × kale DM utilization (%) ÷ 10 (number of dry cows/break).

All dry cows were weighed at the beginning (9 June 2008) and the end (21 July 2008) of the six-week grazing period. At the same time, BCS was assessed by two experienced technicians using the 1-10 NZ scale; the average BCS per cow was then used for statistical analysis.

2.5 Statistical analysis

Data were analysed using GenStat (Version 14, VSN International Ltd, Hemel Hempstead, UK). Whole plant quality was calculated from the weighted leaf and stem fractions based on measured leaf to stem ratio (DM basis). Repeated measurements was conducted for pre-and post-grazing DM yield, kale DM utilization, and leaf to stem ratio with “three replicates” as block and “sowing date × cultivar” as treatment and “sampling date” as variable. General ANOVA was conducted for the quality change of five sections of kale plants with “three replicates” as block and “sowing date × cultivar × five sections” as treatment. General ANOVA was also conducted for whole plant quality, dry cow intake, changes of LW and BCS with “three replicates” as block and “sowing date × cultivar” as treatment.

3. RESULTS

3.1 Pre- and post-grazing dry matter yield and utilization

Pre-grazing forage yield ranged between 12,500 and 18,500 kg DM/ha, and post-grazing forage yield was between 800 and 2,600 kg DM/ha (Figure 1). No difference was found between cultivars for both pre- and post-grazing yield (Figure 1A and C), apart from a higher pre-grazing DM yield observed for SC than for LR in the last two measurement weeks (Figure 1A). A higher pre-grazing yield was observed for NOV kale compared with DEC kale (Figure 1B). On the 9 June, 23 June, and 30 June 2008, the NOV kale had 35, 56 and 84% higher post-grazing yield than DEC kale, respectively (Figure 1D). The average DM utilization of kale crops were 89.2, 89.5, 88.5 and 90.2 % of pre-grazing DM yield for LR, SC, NOV, and DEC, respectively, with no difference detected among treatment groups.

3.2 Kale quality

More than 25% of the total kale DM yield came from leaf and the rest was almost equally distributed between the four stem sections (Table 1). The cultivar 'Regal' had a higher percentage of leaf (33.6%) than 'Caledonian' (25.6 %), 'Regal' had lower NDF (32.4 *vs* 34.1 %), but similar ME content (12.1 *vs* 12.1 MJ/kg DM) in the whole plant compared to 'Caledonian'. There was no difference in the ME content of the kale in the sowing date × cultivar treatments. Nitrogen content was significantly different ($p < 0.001$) between sowing dates. The DEC treatment had N content that was 24% higher than the NOV treatment (Table 1). Across all treatments, ME and N contents were lower in the stem sections than in the leaf. On the other hand, NDF content was higher in the stem sections compared with the leaf (Table 1).

3.3 Apparent dry matter intake, body condition score gain, and liveweight gain

There was no difference aDMI of kale, LW gain, BCS gain, and ME intake for cows in the kale cultivar or sowing date treatments (Table 2).

[Insert Table 1, 2 and Figure 1 here]

4. DISCUSSION

4.1 Pre- and post-grazing yield

Higher yield of kale was achieved for early sowing (NOV) compared with late sowing (DEC). The extended growing season and earlier canopy closure of the NOV sown crop contributed to the growth advantage driven by higher thermal time exposure and higher integral of daily solar radiation interception by the canopy (Brown *et al.,* 2007; Wilson *et al.,* 2004). There was a large variation in post-grazing yield (800 to 2600 kg DM/ha) across the treatments. There were a number of explanations for this such as temporal cow adaptation to biomass on offer, variation in the estimated biomass on offer within and across the experimental area, and the impact of weather related events. The lowest residual was observed in the last week of June when a snow event with accompanying low ambient temperatures (average daily temperature was 2^{o}C and absolute minimum of -4^{o}C). Cows are known to increase their intake to match their increased ME maintenance requirement (Nicol & Young, 1981 and Nicol & Brookes 2007) during periods of cold stress. In addition, the snow caused a loss in efficiency of residue recovery, as there was a higher proportion of plant material buried in the soil and not recovered. There was high level of DM utilization with a consistent amount of residual material in the four treatments. The DM utilization achieved in this study was comparable to the utilization results obtained in 49 kale paddocks grazed by dairy cows in Canterbury (Judson & Edwards 2008), which had an average utilization of 80% of the pre-grazing DM standing biomass.

4.2 Crop quality

The leaf fraction represented between 25 and 34% of the total kale plant DM yield. This was lower than the average of 38.4% reported by Gowers & Armstrong (1994), but within the range (24 to 44%) reported by Judson & Edwards (2008). Leaf had the highest N content, lowest NDF% and lowest WSC% (on DM basis). The ME content for all treatments decreased from leaf to the lower stem, and with the lower three sections (upper mid, lower mid and lower stem). The lower three sections of LR had a higher ME content than SC, similar to the observation made by Judson & Edwards (2008). The LR contained less NDF in the lower three sections of the plants compared with SC, and this decrease in NDF of LR corresponded with an increased digestibility and consequently higher ME (CSIRO, 2007). Fraser *et al.* (2001) suggested that early sowing may cause a loss in the quality of the whole crop through ageing and progressive lignification. Lower N content of the NOV compared with DEC kale in the current study supported the observation of a general decline in quality with earlier sowing, but there was no difference in the NDF or ME values in the respective sowing date treatments.

4.3 Intake, body condition gain, and live weight gain

Over the six-week feeding period, the average LW gain across all treatments was 25 kg (range 22.3-28.0 kg), which was within the range of reported values by Keogh *et al.* (2009a & 2009b) and Greenwood *et al.* (2011). The metabolic energy value of feed during the winter grazing period is important for adding to animal body condition and values in excess of 11.5 MJ ME/kg appear to be effective in achieving the gain in BCS. In our study, the cow body condition gain over six weeks was 0.44 (range 0.43–0.46) across all treatments, and this was higher than previously reported (0.23 over eight weeks feeding period from Greenwood *et al.*, 2011) for non-lactating cows fed around 10 kg DM of kale/cow.day The mean crop quality was high at (~ 12 ME MJ/kg DM) in our study in comparison with the average reported (~ 11.5 ME MJ/kg DM) by Judson & Edwards (2008) and Greenwood *et al.* (2011).

There was no difference in total aDMI (kale + straw) and ME intake. These are likely to be the valid reasons for the lack of difference in LW gain and BCS gain across treatments. It is important to note that the target of 0.5 body condition gain was not achieved in the current study, although the calculated ME intake (kale + straw) in Table 2 (~ 130 MJ ME/cow.day) was higher than the recommended 115 MJ ME/cow.day (Nicol & Brooks 2007) for optimum performance. Greenwood *et al.* (2011) also observed that cows did not achieve 0.5 body condition gain despite an adequate intake of ME. This may have been due to an underestimation of the maintenance ME requirement for the dry cows. Mandok *et al.* (2013) conducted a study to estimate the maintenance cost of 52 non-lactating, pregnant dairy cows in NZ. This showed a daily maintenance requirement of 0.94 MJ ME/kg $LWT^{0.75}$ rather than the 0.55 MJ ME/kg $LWT^{0.75}$ from Nicol & Brooks (2007), which has been widely used for estimating the intake requirements of pregnant, non-lactating pregnant cows. Further research is needed to determine the reasons for this higher ME requirement for body condition gain. Factors such as animal size, the extent of energy loss/increment as heat and anti-nutritional components in feeds are important for optimizing allocation and decision on animal management. Management of grazing in the trial was designed to replicate a commercial wintering operation in Canterbury, NZ where large scale single grazing of kale is common practice. It is important to note the limitations of this grazing study: it was only conducted for a period of 42 days, in one year and on a single site. From our study, it appears that options are limited for improving the quality of kale through cultivar selection or timely sowing of the crop, and it has less influence than management of the grazing process itself. Future studies should verify the crop and animal interactions over longer period, multiple sites and seasons.

5. CONCLUSIONS

Early sowing of kale (November) increased the pre-grazing DM yield, but led to lower plant quality (i.e. N content). A leafy kale cultivar 'Regal' contained less NDF compared with a stemmy cultivar 'Caledonian'. Under the feeding conditions in the trial, the ME intake was similar across four treatments and no treatment differences (cultivar choice or sowing time) were found for BCS or LW gain over the winter grazing period. Future studies should verify the crop and animal interactions over longer period, multiple sites and seasons.

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Figure 1. Pre-grazing yield (**A**) and (**B**), and post-grazing yield (**C**) and (**D**) of kale from two cultivars (**A**) and (**C**), and sowing dates (**B**) and (**D**) (• represents Regal ◦ represents Caledonia ▲ represents November sowing Δ represents December sowing) offered to non-lactating, pregnant dry dairy cows. Error bar = SEM

Table 1 Chemical composition (DM basis) of five fractions of pre-grazing kale for two sowing dates and two cultivars

	Five sections	% of total DM	Metabolisable energy (MJ/kg DM)	Nitrogen (% of DM)	Neutral detergent fibre (% of DM)	Water soluble carbohydrate (% of DM)
Sowing date						
November	Leaf	27.4	13.0	3.7	25.2	16.4
	Upper	17.7	13.8	2.3	27.8	45.0
	Upper mid	18.1	12.2	1.7	37.3	43.7
	Lower mid	18.5	10.3	1.3	47.7	39.2
	Lower	18.4	10.5	1.2	45.7	38.6
December	Leaf	31.8	12.6	4.0	26.0	13.8
	Upper	16.6	13.9	2.7	27.6	42.8
	Upper mid	16.9	12.8	2.2	35.0	40.6
	Lower mid	17.3	11.0	1.5	44.4	39.6
	Lower	17.5	9.6	1.4	51.6	35.5
Cultivar						
Caledonia	Leaf	25.6	12.8	3.9	24.8	15.1
	Upper	18.1	13.9	2.4	27.6	45.3
	Upper mid	18.5	12.3	1.9	38.1	40.0
	Lower mid	18.9	10.3	1.4	48.1	39.7
	Lower	19.0	9.4	1.3	52.9	36.0
Regal	Leaf	33.6	12.8	3.8	26.5	15.2
	Upper	16.2	13.8	2.6	27.8	42.5
	Upper mid	16.5	12.7	1.9	34.2	44.4
	Lower mid	16.8	11.0	1.5	44.0	39.0
	Lower	16.9	10.7	1.3	44.4	38.0
Significance (sowing date)		NS	NS	***	NS	NS
SED (sowing date)		0.25	0.12	0.07	0.84	1.05
Significance (cultivar)		NS	***	NS	***	NS
SED (cultivar)		0.25	0.12	0.07	0.84	1.05
Significance (five sections)		***	***	***	***	***
SED (five sections)		0.40	0.19	0.12	1.32	1.67
Significance (sowing date × cultivar)		NS	NS	NS	NS	NS
Significance (sowing date × five sections)		***	**	NS	*	NS
Significance (cultivar × five sections)		***	**	NS	**	NS
Significance (sowing date × cultivar × five sections)		*	NS	NS	NS	NS

NS-not significant; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

Table 2 Dry matter intake, liveweight gain, body condition gain, and metabolizable energy intake of pregnant, non-lactating dry dairy cows fed kale sown at two sowing dates and with different leaf to stem ratio

	Dry matter intake of kale (kg/cow.day)	Total dry matter intake (kg/cow.day)	Liveweight gain (kg/six weeks)	Body condition gain (unit/six weeks)	Metabolizable energy intake (kale + straw; MJ/cow.day)
Sowing date					
November	9.4	11.4	24.7	0.45	128.4
December	9.6	11.6	25.5	0.43	130.5
Cultivar					
Caledonia	9.6	11.6	28.0	0.43	129.3
Regal	9.5	11.5	22.3	0.46	129.6
Significance (sowing date)	NS	NS	NS	NS	NS
SED (sowing date)	0.19	0.19	3.19	0.021	1.95
Significance (cultivar)	NS	NS	NS	NS	NS
SED (cultivar)	0.19	0.19	3.19	0.021	1.95
Significance (sowing date × cultivar)	NS	NS	NS	NS	NS
SED (sowing date × cultivar)	0.27	0.27	4.51	0.03	2.76

NS-not significant; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$