Effect of timing of harvest on nutritive value of four cultivars of kale (*Brassica oleracea* L. *var. acephala*)

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Abstract

A single site, single year replicated study in Canterbury investigated change in nutritive value and dry matter (DM) yield of four kale cultivars harvested monthly between May and September.

The proportion of leaf relative to stem was significantly higher for an intermediate kale ('Regal') and short marrow-stem kale ('Kestrel') compared with two giant kales 'Gruner' and 'Rawera'. Late winter loss of leaf was greater for 'Gruner' and 'Rawera' compared with 'Regal' or 'Kestrel'. Whole plant DM% remained stable through winter (average 11.9%). Lower stem contained more DM than top stem or leaf. The DM% of 'Gruner' was significantly higher than other cultivars. 'Kestrel' contained significantly more megajoules of metabolisable energy than other kales. Energy content of leaf and top sections of stem averaged 2.5 MJME/kg DM more than lower stem.

Dry matter yield peaked in June then declined monthly thereafter for giant kales 'Gruner' and 'Rawera', but not 'Regal' or 'Kestrel'. The use of intermediate and short marrow-stem kales 'Regal' and 'Kestrel' is one management option to improve the leafiness and whole plant energy content of late winter feed crops.

Keywords: Forage brassica, kale, nutritive value, winter feed, yield

Introduction

Kale (choumollier; *Brassica oleracea* L. var. *acephala*) delivers high yields of dry matter (DM) in cooler South Island and central North Island regions. Traditionally late spring sown kale is consumed by cattle, sheep or deer during June and July the following year. Some farmers defer the *in situ* grazing of kale until late winter as a way to "carry" a relatively low cost supplementary feed and to allow the accumulation of spring pasture. Anecdotal reports of late winter loss of leaf and hardening of stems suggest deferred grazing may reduce the quality of late grazed winter kale. The range of available kale ecotypes with different plant attributes, leaf to stem ratios and stem characteristics indicate that some may be better suited than others for late winter grazing.

The aim of this research was to quantify change of nutritive value and DM yield for four types of irrigated kale: one short marrow-stem, one intermediate and two giant types, harvested at monthly intervals between May and September in Canterbury, New Zealand.

Materials and Methods

A randomised complete block experiment with four replicates was established under irrigation into a Templeton silt loam soil at Kimihia Research Centre, Lincoln, Canterbury. Four kale cultivars (intermediate type kale 'Regal', short marrow-stem kale 'Kestrel' and "giant" type kales 'Gruner' and 'Rawera') were established on 27 November 2012 following cultivation at a sowing rate of 4 kg of bare seed/ha following incorporation of 250 kg/ha of Cropmaster Brassica + Boron (13.9:15.4:9.5:0.8; Ravensdown, New Zealand). Urea was applied at 175 kg/ha on day 51 prior to canopy closure. Plot sizes were 3 m × 15 m with a 3 m buffer of non-sampled kale at the north and south boundaries of each block.

Beginning on 13 May 2013, sequential monthly harvests of whole plants from three replicates of each cultivar were harvested 167, 192, 223, 258, and 286 days after sowing (DAS) with each harvest defined as "May", "June", "July", "August" and "September". At the May and June harvests, replicates 1, 2 and 3 were harvested for nutritive value and DM yield. Replicate 4 was harvested for DM yield only. Following severe north westerly wind damage and plant lodging in late June 2013, replicate 1 was abandoned and replaced by replicate 4. At each of the July, August and September harvests, replicates 2, 3 and 4 were harvested for nutritive value and DM yield.

At each monthly harvest, a 1 m^2 quadrat of whole plants was harvested from three replicates of each kale cultivar. May quadrat cuts were harvested 2 m from the eastern boundary of each replicate. At subsequent harvests, quadrat cuts were harvested further into each replicate working across each replicate in a westerly direction, with a buffer of at least 1 m maintained from the previous month's harvest.

Kale plants were dissected in the field into leaf and petiole ("leaf"), the top third of the stem ("top stem"),

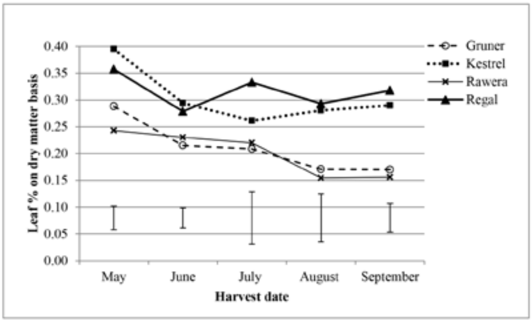

Figure 1 Leaf expressed as a percentage of whole plant dry matter for four kale cultivars. Vertical bars represent $LSD_{P<0.05}$

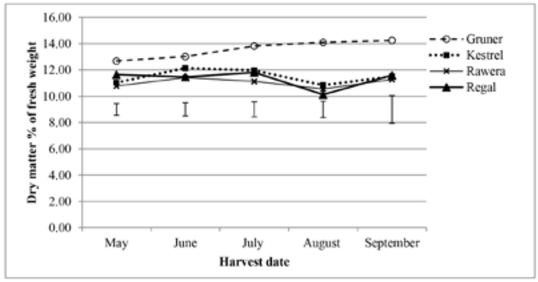

Figure 2 Whole plant dry matter percentage of four kale cultivars, expressed as percentage of plant fresh weight. Vertical bars represent $LSD_{P<0.05}$

the middle third of the stem ("mid stem") and the lower third of the stem cut to ground level ("lower stem"). Dissection of stem sections was on the basis of subjective assessment of one third of the length of each stem following removal of leaf and petiole.

A representative sub-sample of each plant component (leaf, top, mid and lower stem) from each replicate of each cultivar was submitted for DM and nutritive value determination. Samples were submitted to a commercial feed testing laboratory (Hill Laboratories, Hamilton). Dry matter percentage, megajoules of metabolisable energy (MJME), crude protein (CP; as calculated by plant nitrogen content × 6.25), neutral detergent fibre (NDF) and water soluble carbohydrate (WSC) were determined by near infrared spectroscopy (NIRS) for leaf and petiole, and using wet chemistry analytical techniques for stem samples.

Statistical Analysis

The analysis for each date by component by measurement was undertaken using GenStat 14 as separate randomised block analyses, giving significances and least significant differences for comparisons between cultivars. For comparisons between dates, a repeated measures analysis was done. A test for a uniform covariance structure (i.e. a common correlation between times and common variance over times) was calculated using the method of Greenhouse & Geisser (1959), and if the departure from this model was not significant, then this covariance model was used. This is equivalent to a split-plot in time analysis with reduction in the degrees of freedom in the time stratum reflecting the correlation between times. This analysis then gave the significances for differences between times and the cultivar by time interaction. Significance was declared at P<0.05.

Results

Leaf yield relative to stem

'Regal' and 'Kestrel' yielded significantly (P<0.001) more leaf relative to stem than either 'Gruner' or 'Rawera' at all but one harvest (Figure 1). Leaf percentage ranged from 40% ('Kestrel'; May harvest) to 15% of whole plant DM ('Rawera'; August harvest). Change of leaf percentage over time was not significantly (P>0.05) different between cultivars, however late winter leaf percentage for 'Kestrel' and 'Regal' tended to lift compared with either 'Gruner' or 'Rawera' (Figure 1).

Dry matter percentage

'Gruner' was characterised by a significantly higher (P=0.026) whole plant DM% (Figure 2) and stem DM% than other cultivars. Average whole plant DM% ranged from 10.8 to 14.2% for 'Rawera' in May and 'Gruner' in September (Figure 2). Leaf DM% did not differ significantly (P>0.05) between harvest dates (average 11.3% DM). Stem DM% was higher in June and July compared with later harvests. Top section of stem contained less DM as a percentage of fresh weight than either mid or lower stem sections (10.5%, 11.5% and 13.9% DM, for top, mid and lower stem sections, respectively).

Megajoules of metabolisable energy

Average whole plant energy content was 11.4 MJME/kg DM (range 11.2 to 11.8 MJME/kg DM for August and May harvests, respectively). Whole plant energy content of 'Kestrel' was significantly (P=0.005) greater than other cultivars at all harvest dates (Figure 3). All sections of 'Kestrel' stem contained significantly (P<0.001) more MJME/kg DM than other cultivars at all harvest dates. 'Rawera' contained significantly (P<0.001) less energy in August and September, but not in May, June or July. The pattern of change in whole plant energy content over time did not differ significantly (P>0.05) between cultivars.

Over time, whole plant MJME concentration changed from peak in May to a lower content in August followed by a slight increase in September (Figure 3). Energy content was greatest for leaf and top stem (12.6 and 12.5 MJME/kg DM) and lowest for the base

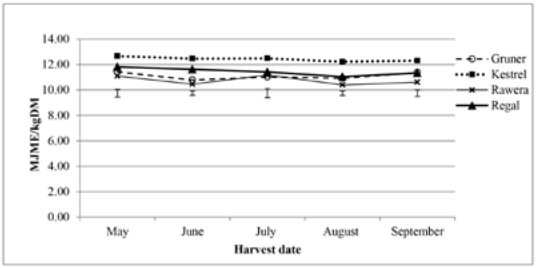

Figure 3 Whole plant energy content (megajoules of metabolisable energy (MJME)/kg DM) of four kale cultivars. Vertical bars represent $LSD_{P<0.05}$

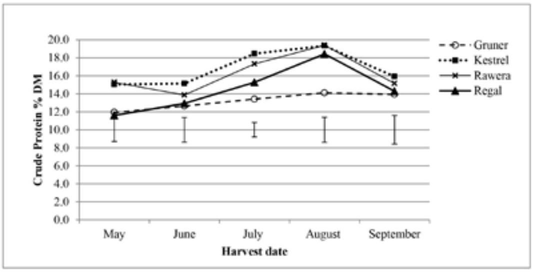

Figure 4 Whole plant crude protein (CP) content of four kale cultivars, expressed as percentge of dry matter. Vertical bars represent $LSD_{p<0.05}$

of the plant (average 9.8 MJME/kg DM). Leaf MJME was significantly (P=0.031) lower at the May harvest (12.2 MJME/kg DM) than the September harvest (13.1 MJME/kg DM). Metabolisable energy of stem tops was significantly (P<0.001) higher in May (12.8 MJME/kg DM) compared to September (12.1 MJME/kg DM). Energy content of the lower third of the stem differed significantly with time, with the August MJME content significantly lower than May (9.1 MJME/kg DM vs 10.8 MJME/kg DM).

Crude protein

Whole plant CP content was significantly influenced by cultivar, however between-cultivar differences were neither repeatable nor consistent at each harvest. 'Gruner' contained less CP than other cultivars at two out of five monthly harvests (Figure 4). Levels of whole plant CP declined between August and September harvests for 'Kestrel', 'Regal' and 'Rawera' but not 'Gruner' (Figure 4). Kale leaf contained high levels of CP compared with stem (average 25.2% CP for leaf compared with 9.0% CP for the lower third of the stem). Top stems contained on average 16.0%, and mid stems 12.2% CP. From relatively low levels in May, leaf and top stem CP levels peaked in August at 30.4% CP.

Neutral detergent fibre

'Kestrel' contained significantly (P<0.001) less NDF than other kale cultivars. Whole plant NDF content

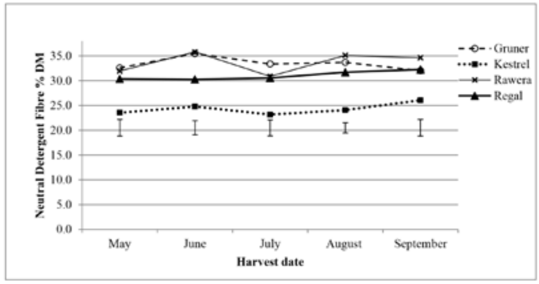

Figure 5 Whole plant neutral detergent fibre content of four kale cultivars, expressed as percentage of dry matter. Vertical bars represent $LSD_{P<0.05}$

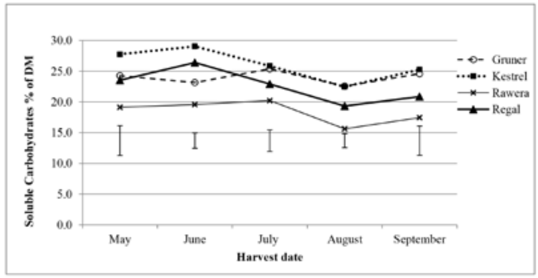

Figure 6 Whole plant water soluble carbohydrate content of four kale cultivars, expressed as percentage of dry matter. Vertical bars represent $LSD_{P<0.05}$

remained relatively constant at all harvests (Figure 5). For all cultivars, leaf contained less NDF than stem, and lower stem contained more NDF than top stem. Lower stem NDF content increased slightly from 38.3% in May to 44.0% NDF in September. Minor time related changes in NDF were seen between May and September for mid stem (32.0 to 34.2% NDF, May and September) and top stem (23.9 and 27.7% NDF). Conversely, leaf NDF levels declined significantly (P<0.001) through winter.

Water soluble carbohydrates

Whole plant kale contained on average 22.8% WSC. On a whole plant basis, 'Rawera' contained significantly (P=0.034) less WSC than 'Gruner' and 'Kestrel' at every harvest (Figure 6). Leaf contained less WSC (average 14.7%) than top and mid sections of the stem (27.0 and 26.7% WSC, respectively). Harvest date was significantly (P<0.001) associated with whole plant WSC levels (Figure 6). Average whole plant WSC levels were highest in June and lowest in August (24.5% and 20.0%, respectively). Leaf WSC level was significantly (P<0.001) influenced by harvest date with a peak of 16.5% in June and September and a relatively lower content of 11.5% in August. Similarly, stem WSC content dropped from an initial peak in May to lowest levels in August.

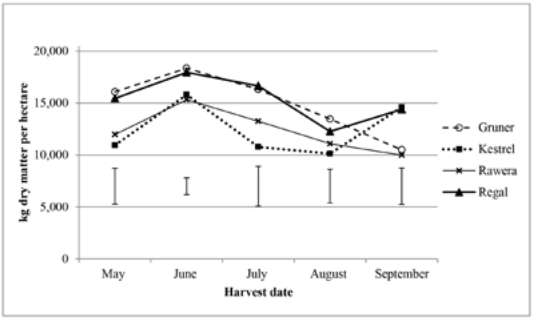

Figure 7 Yield of dry matter (kg DM/ha) of four kale cultivars. Vertical bars represent $LSD_{P<0.05}$

Dry matter yield

Across all sampling months, 'Kestrel' tended (P<0.17) to yield less whole plant DM compared with other cultivars (Figure 7). Average dry matter yield for all cultivars declined significantly (P<0.001) from June to September (16 861 kg DM/ha and 12 374 kg DM/ha, respectively).

Discussion

The nutritive value of four kale cultivars changed significantly during winter in this single site, single year study. Leaf percentage remained unexpectedly high throughout winter, at odds with field observations of apparent less leaf and a greater predominance of stem when kale plants are carried through winter. The mean winter 2013 air temperature of 8.1°C recorded at Lincoln, Canterbury was the warmest on record since records began in 1881 (Anon 2013). Unseasonally warm temperatures, fewer frosts and an absence of snow may have minimised senescence of leaf and/or promoted a faster rate of late winter leaf appearance, for 'Kestrel' and 'Regal' particularly. Kale cultivar influenced leaf percentage, with the intermediate kale ('Regal') and short marrow-stem kale ('Kestrel') yielding more leaf than either 'Gruner' or 'Rawera'. Where more leaf is required for better animal performance, particularly later in winter, use of 'Kestrel' and 'Regal' should be considered ahead of "giant" type kales.

Whole plant energy content on average declined with advancing winter, driven by deterioration of quality of stem but not leaf. The MJME content of late winter leaf increased because pre-inflorescence elongation of petiole increased the ratio of petiole to leaf, and true leaf contains less energy than petiole (Westwood & Mulcock 2012). 'Kestrel' contained more whole plant MJME than other cultivars due to a higher ratio of leaf to stem and a higher MJME content of 'Kestrel' stem. In mild winters and where crops are not at risk of lodging, carrying of leafy kales, particularly 'Kestrel' and 'Regal' is one strategy to successfully carry high MJME feed through winter.

Whilst 'Kestrel' tended to yield less DM than other cultivars, energy yield (MJME) per hectare was similar for all cultivars at three out of five harvests. When energy-dense crops are required and/or when crop utilisation may be constrained by harvesting challenges, for example eruption of permanent teeth by young cattle, use of kales with softer, low NDF stems ('Kestrel') and more leaf relative to stem ('Kestrel' and 'Regal') should be considered. This is particularly true for modern intermediate type kales, such as 'Regal', that match or exceed DM yields of older 'giant' types whilst offering relatively more leaf, particularly late in winter.

'Gruner' contained more DM per unit fresh weight than other cultivars; further all DM% values were low compared with an average whole plant kale DM% of 17.3% reported for eight cultivars of kale (Westwood & Mulcock 2012). Between-cultivar variance, different DM% of plant fractions and probable site and season modifiers of DM% highlight the need to sample multiple whole plants when undertaking DM yield assessments. Use of "book value" standardised kale DM% values should be discouraged.

Whole plant protein CP averaged 15.2% in contrast to average levels of 9.7% CP for eight kale cultivars (Westwood & Mulcock 2012). Higher CP levels reflected appropriate use of N fertiliser and adequate plant available N in the current study, as well as increased rate of leaf appearance during an unseasonably mild winter. Unexpectedly, whole plant CP content increased with time for all cultivars except 'Gruner'. In contrast, Fraser *et al*. (2001) reported diminishing levels of whole plant kale CP content throughout winter, while Kunelius *et al*. (1989) reported stable CP levels in 'Kestrel' during late autumn and winter. Warm soil conditions, ongoing soil N mineralisation and remobilisation of N from senescing older leaves into growing tips may explain the high late winter content of CP.

Whole plant NDF remained constant throughout winter, at odds with anecdotal field reports of "woody, high NDF" late winter kale. Whilst stem concentration of NDF increased slightly with DAS, leaf NDF content diminished with time, stabilising whole plant NDF content. Whole plant 'Kestrel' contained 30% less NDF than other kale cultivars, reflecting not only more leaf relative to stem, but also lower NDF content for each of the three sections of stem. Cows that laxly graze *ad libitum* kale, particularly 'Kestrel' will ingest predominantly leaf, petiole and top stem and this may increase risk of ruminal acidosis.

Level of WSC differed significantly between cultivars, with 'Rawera' containing low WSC levels compared with other cultivars. For all cultivars, mean WSC level was low (22.8%) compared with a mean value of 33.4% reported for eight kale cultivars

(Westwood & Mulcock 2012). Warm temperatures and few frosts may have reduced WSC content because frosting can be associated with accumulation of WSC in winter active plants.

Dry matter yield data showed trends for an inverse relationship between DM yield and DAS. Kunelius *et al.* (1989) also reported a negative association for kale between DM yield and DAS. In contrast, yield was not associated with DAS for kale harvested at 105, 126 and 140 DAS (year one) and 98 or 119 DAS (year two; Fraser *et al.* 2001). Plant counts (plants per m^2) did not change significantly during winter (data not shown) therefore mechanisms that change winter DM yield including the role of leaf senescence and/or leaf recovery and regrowth should be the subject of further investigation. Care is required with the interpretation of these data due to the single site, single year study design. Repeated yield harvests across multiple sites and sequential years would better define change in DM yield under a range of different environments.

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