Investigations of alternative kale management: Production, regrowth and quality from different sowing and defoliation dates

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Abstract
Gruner kale showed a linear increase (8.0 kg DM/ha per °Cd) in biomass with sowings on 1 October, 3 November and 1 December producing 23, 19 and 17 t DM/ha (respectively) by the 29 May. Regrowth following mid season defoliation was slow (5.3 kg DM/ha per °Cd) reducing total production (relative to undefoliated) by 7.5 and 5.5 t DM/ha for treatments defoliated on the 29 January and 14 March, respectively. Leaf biomass increased to a ceiling yield of 3.1 t DM/ha at 1620 °Cd after sowing. Defoliation on or after this time allowed additional (0.9 – 1.4 t DM/ha) regrowth but is unlikely to offset the reduced total production suggesting defoliation is not a viable option for kale. A second experiment showed no significant difference in the regrowth potential of Gruner and Kestral kale. Increasing cutting height from 10 to 60 cm reduced total DM production from 15.6 to 11.8 t/ha and reduced the amount of leaf DM produced from 5.1 to 4.2 t/ha.
Keyworks: defoliation, kale, quality, regrowth, sowing date, thermal time, yield

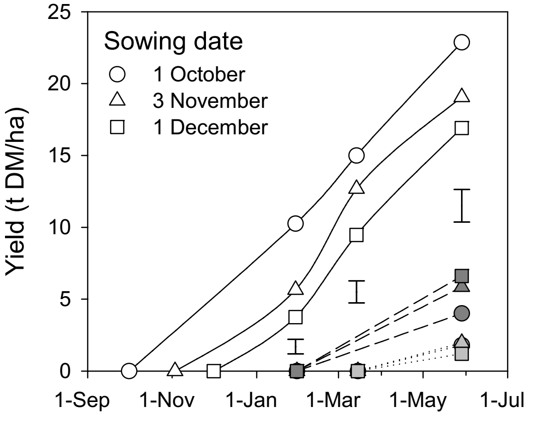
Introduction
Traditionally kale is sown in December and utilised by a single grazing in winter. Yield potential (in the absence of water and nutrient limitation) is determined by the amount of thermal time (daily temperature sum) and solar radiation (sunlight) that the crop experiences (Wilson *et al*. 2004). Thus, sowing kale earlier than December would allow the crop to experience more thermal time and solar radiation, giving greater yield potential. However, potential benefits of earlier sowing may not be realised if the crop reaches a ceiling yield before the growth season finishes (in winter). Earlier sowing will also mean the crop is more mature when it is grazed in winter, which could reduce forage quality (Fraser *et al*. 2001). Of the first 10 t DM/ha produced by kale, 30 – 40% is leaf and the remainder is stem (Fletcher *et al*. 2007). Subsequent growth from a kale crop is all stem with leaf biomass remaining constant at 3 – 4 t DM/ha. Leaf is generally the higher quality fraction of the kale with a higher digestibility and crude protein content (Stephen 1976). Thus, defoliating a kale crop in the middle of the growing season to utilise the high quality leaf and then allowing it to regrow a second lot of leaf for winter feed may improve the quality of the biomass utilised from the crop. The possibility of summer grazing of kale crops will also increase the flexibility of kale as a forage option. Newton *et al*. (1987) have shown that kale is able to regrow following grazing. However, there are no data available comparing production from different combinations of sowing and cutting dates under high input (fertiliser, insecticide and irrigation) systems. Thus, the objective of this research was to measure the influence of earlier sowing and mid season defoliation on kale yield and quality.

Materials and Methods
Experiments were conducted at A block on the Crop and Food Research farm at Lincoln in Canterbury. The soil is a Templeton silt loam and was in mown ryegrass pasture for 2 years prior. The site was cultivated using standard practices (plough, cultivate). There was 174 kg/ha of mineral N in the soil (to 1 m depth) prior to sowing and the site had a pH of 6.1, Olsen P of 11 and K of 7. Fertiliser was applied to meet the crops requirements determined using the Kale Calculator (Wilson *et al*. 2006). Trials received 200 kg/ha of DAP and 15 kg/ha of Boronate prior to sowing and a further 228 – 300 kg N/ha (depending on requirement) as urea in three applications during the growing season. Seed was drilled in 15 cm rows at 4 kg/ha. Herbicide and insecticide were applied as necessary to control weeds and insect pests. Spray irrigation was applied to replace evapotranspiration losses and ensure the crops were not water stressed.

Experimental design
Two experiments were conducted, a sowing by cutting date trial using Gruner kale (Experiment 1) and a cultivar by cutting height trial (Experiment 2).

Experiment 1 was a split plot with four replicates of three mowing treatments as main plots. These were: 1. Early season mowing where the crop was mown with a disc mower (20 cm above ground level) on 29 January and allowed to regrow for a second mowing 29 May; 2. Mid season mowing where kale was mown on 14 March and regrew for a second mowing on 29 May; 3. Late mowing on 29 May only. The sub-plots were three sowing dates on 1 October, 3 November and 1 December 2006. Each plot was 12 by 1.35 m and had buffer plots of the same size (receiving the same treatment) on either side.

Figure 1 Biomass accumulation of Gruner Kale from three different sowing dates (solid lines) and regrowth from 29 January (dashed lines) and 14 March (dotted lines) mowings. Bars represent one least significant difference for comparing different sowing dates within each cutting date.



Experiment 2 was a split plot with four cutting heights as main plots, 10, 20, 40 and 60 cm above ground level. Sub plots (10 by 1.35 m) were two different kale cultivars, Gruner and Kestral. This experiment was sown on 1 October 2006, cutting height treatments were imposed on 29 January 2007 and regrowth from these cuttings was measured (20 cm above ground level) on 30 May 2007.

Measurement

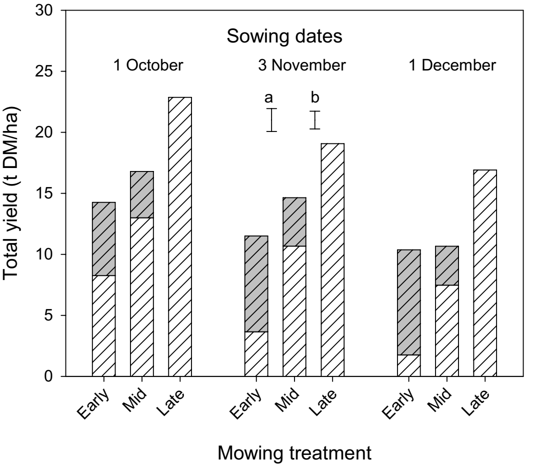
A sample of 3 m^2 was cut to the appropriate cutting height in each plot on each cutting date. The fresh mass of this sample was recorded in the field and a weighed sub-sample of 10 plants was taken back to the laboratory. Sub-samples were separated into stem and leaf fractions, dried and weighed to determine DM content and leaf and stem percentages of each treatment. Dried samples from the final cutting date (29 May 2007) were ground and analysed (using Near Infrared Reflectance Spectroscopy, NIRS) to give estimates of digestibility and nitrogen content.

Results and Discussion

Biomass production from different sowing and mowing dates (Experiment 1)

The pattern of biomass accumulation of each of the treatments in Experiment 1 is shown in Figure 1. The first sowing date (1 October 2006) continued to accumulate biomass between each cutting, reaching 10 t DM/ha on 29 January, 15 t DM/ha on 15 March and 23 t DM/ha on the final cutting date (29 May 2007). This was greater (P<0.001) than the biomass production of

Figure 2 Total yield of Gruner kale from three sowing dates in combination with three mowing treatments. The early and mid treatments were mown on 29 January 2007 and 14 March 2007, respectively. All treatments were mown on 29 May 2007 and the grey shaded areas represent regrowth from the early and mid cutting treatments. Bars marked with a and b represent LSDs for comparison of mowing and sowing date treatments, respectively.



the 3 November and 1 December sowings which produced 19 and 17 t DM/ha (respectively) by the final cutting date (Figure 2). Total yields are consistent with yields reported in other high input kale crops (Fletcher *et al*. 2007; Wilson *et al*. 2006).

The early mowing treatments regrew another 5 t DM/ha between 29 January and 29 May while the undefoliated treatments grew 12 t DM/ha (Figure 1). Similarly, the mid mowing treatment regrew 2 t DM/ha between 14 March and 29 May while the undefoliated treatments grew 6.5 t DM/ha. So, overall, a mowing on 29 January or 14 March reduced (P<0.001) total yield by 7.5 and 5.5 t DM/ha, respectively, compared with the treatment that was not cut until the end of the season (Figure 2). This differs from the results of Newton *et al*. (1987) who showed total yields of kale sown in November and regrown from a January grazing were the same as for an undefoliated crop (10 t DM/ha). This yield is consistent with the November sowing and early mowing treatment reported in this paper (Figure 2) showing regrowth rates were similar in both experiments. The undefoliated treatment was probably less productive for Newton *et al*. (1987) because of aphid burden and lower fertiliser inputs.

The cause of differences in cutting and mowing treatments was analysed by plotting biomass accumulation against thermal time (sum of daily mean temperature above a base of zero) accumulated from sowing or defoliation date. Biomass showed a linear increase of 8.0 kg DM/ha per °Cd, beginning 350 °Cd after sowing (Figure 3a). Thus, the greater yields from the earlier sown crops were because they experienced more thermal time before the end of the season. The 350 °Cd intercept represents the lag from sowing until rapid leaf area expansion begins. The lag for regrowth was longer than this, taking 660 °Cd to become linear and, thereafter yield accumulated at a rate of 5.3 kg DM/ha per °Cd. It was expected that defoliation would reduce yield because there is a period when leaf area is regrowing and the crop is not intercepting all solar radiation or growing at its potential. However, the longer lag period for the regrowth crops and the lower regrowth rate compounded the effects of defoliation reducing yield further than expected.

Biomass production from different mowing heights (Experiment 2)

There were no cultivar differences in kale first cut DM yield, regrowth DM yield or total DM yield (Table 1). Reducing cutting height from 60 to 10 cm increased (P<0.001) the amount of kale harvested on the 29 January mowing from 3.6 to 9.8 t DM/ha. Residuals were 0.9 t DM/ha for the 10 cm cutting height, increasing to 7.1 t DM/ha for the 60 cm cutting height. The opposite trend was measured at the final cutting (29 May) where yield increased (P<0.001) from 5.9 t DM/ha for the 10 cm cutting height to 8.2 t DM/ha for the 60 cm cutting height. However, the sum of the two cuttings was greatest (P<0.001) for the 10 cm cutting height (15.6 t DM/ha) and decreased to 11.8 t DM/ha at the 60 cm cutting height (Table 1). Subtracting the residual of the first mowing from the yield measured at the final harvest suggests biomass produced in regrowth increased from 1.1 t DM/ha from the 60 cm cutting height to 5.0 t DM/ha for the 10 cm cutting height. Regrowth and old biomass were not distinguished at final harvest. However, field observations suggested that regrowth was the same from all treatments and the lower apparent production from the higher cutting heights was because of a loss of biomass from the residual stem. This suggests that it is not beneficial to leave a larger residual after defoliation events because much of what is left is lost by respiration with no apparent benefit to regrowth.

Leaf and stem production

There was an interaction (P<0.01) between sowing and cutting dates with all sowing dates producing ~3 t DM leaf/ha for the late mowing treatment (Table 2). The treatments that were cut early and allowed to re-grow all produced more (P<0.01) leaf than this (3.8 – 4.4 t DM/ha) except the treatments that were sown on 3 November and 1 December and mown on 29 January. The influence of different sowing and cutting date treatments on leaf production can be explained by plotting leaf production against thermal time accumulation (Figure 3b). There was a linear accumulation of leaf biomass at a rate of 2.4 kg DM per °Cd until a ceiling leaf yield of 3.1 t DM/ha had accumulated, 1620 °Cd after sowing. Thus, treatments that were defoliated when leaf biomass had reached 3.1 t DM/ha had the opportunity to produce more regrowth. However, following defoliation, leaf regrew at a slower rate (Figure 3b) so the combination of later sowing and early mowing meant crops that were mown before they had produced 3 t DM/ha were not able to make up the difference due to slower regrowth. This shows that any planned defoliation should be timed to occur 1620 °Cd after sowing to ensure ceiling leaf yield is produced in the first growth and to maximise the

Figure 3 Biomass (a) and leaf (b) production of Gruner kale from three sowing dates and regrowth from mowings on 29 January (dark grey symbols) and 14 March (light grey symbols). Regression in plot a, from sowing y = 0.008x - 2.7 (R^2 = 0.99), from regrowth y = 0.005x - 3.5 (R^2 = 0.85). Broken stick regression in plot b, y = 0.0024x – 0.97 (x > 1620) y = 3.09(x ^{3} 1620) (R^2 = 0.98).

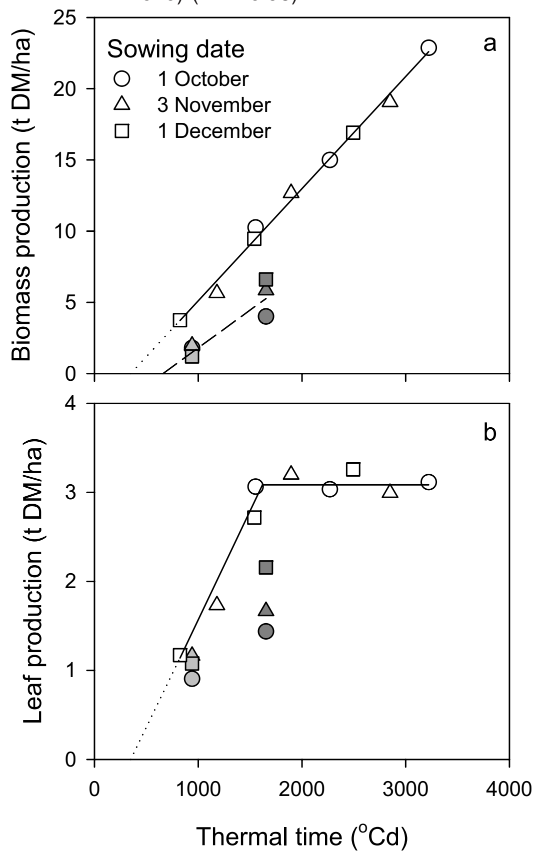


Table 1 Leaf, stem and total biomass yields (t DM/ha) of Kestral and Gruner kale crops mown at different heights on 29 January 2007 and regrowth from this mowing (grey shaded values) harvested to ground level on 30 May 2007.

	Sown on 6/10/06 Cut on 29/01/07			Regrown from 30/1/06 Cut on 30/05/07			Total production		
	Leaf	Stem	Total	Leaf	Stem	Total	Leaf	Stem	Total
Mowing Height									
10cm	3.1	6.6	9.8	1.9	3.9	5.9	5.1	10.6	15.6
20cm	3.1	5.7	8.9	2.1	4.5	6.6	5.2	10.2	15.4
40cm	2.5	3.3	5.7	2.2	5.4	7.6	4.7	8.6	13.3
60cm	1.9	1.7	3.6	2.3	5.9	8.2	4.2	7.7	11.8
P	***	***	***	ns	***	***	***	***	***
LSD	0.31	0.37	1.00	-	0.81	1.00	0.45	1.14	1.52
Cultivar									
Gruner	2.8	5.0	7.8	2.0	5.2	7.2	10.2	4.8	15.0
Kestral	2.5	3.7	6.2	2.3	4.7	6.9	8.4	4.7	13.1
P	ns	ns	ns	ns	ns	ns	ns	ns	ns

Table 2 Leaf and stem biomass yields (t DM/ha) of Gruner kale from a combination of three different sowing and mowing treatment combinations. Grey shaded cells on the final harvest date represent regrowth from early and mid mowing treatments.

		Harvest date 29/01/07		14/03/07		29/05/07		Total	
Mowing	Sowing date	Leaf	Stem	Leaf	Stem	Leaf	Stem	Leaf	Stem
Early	1-Oct-06	3.1	5.2			1.4	4.6	4.5	9.8
	3-Nov-06	1.7	1.9			1.7	6.2	3.4	8.1
	1-Dec-06	1.2	0.6			2.2	6.5	3.3	7.0
Mid	1-Oct-06			3.0	10.0	0.9	2.9	3.9	12.9
	3-Nov-06			3.2	7.5	1.2	2.8	4.4	10.3
	1-Dec-06			2.7	4.7	1.1	2.1	3.8	6.9
Late	1-Oct-06					3.1	19.7	3.1	19.7
	3-Nov-06					3.0	16.1	3.0	16.1
	1-Dec-06					3.3	13.7	3.3	13.7
	Ps	***	***	ns	**	ns	ns	*	***
	Pc	-	-	-	-	***	***	ns	***
	Psxc	-	-	-	-	ns	***	**	ns
	LSD*	1.40[1]	1.13[1]	-	1.39[1]	0.32[2]	1.81[2]	0.31[3]	1.43[1] 1.18[2]

Note: P_S = probability of sowing date main effect. P_C = probability of cutting date main effect. Psxc = probability of interaction. * Superscripts on LSD values: 1 = LSD for comparison of sowing date means, 2 = LSD for cutting date means, 3 = LSD for comparison of cutting date means within the same level of sowing date.

time for leaf to accumulate in the subsequent regrowth.

Approximately 3 t DM/ha of leaf was harvested from the 10 and 20 cm cutting height treatments on 29 January (Table 1). Increasing cutting height above this reduced ($P<0.001$) the amount of leaf that was harvested as some leaf passed below the cutter bar. Cutting height had no effect on the amount of leaf produced in regrowth so the seasonal totals for leaf production decreased with increased cutting height (Table 1). This shows that cutting height (or grazing intensity) should be 20 cm or lower to maximise leaf production.

There was a strong correlation (R^2=0.98) between stem production and total yield for both experiments, showing treatment differences in yield were caused by differences in stem production.

Herbage quality

It was expected that the earlier sown crops would have stems with higher fibre contents and lower digestibility (Stephen 1976). However, NIRS analysis did not show any differences. We suspect that this is an error due to insufficient calibration of NIRS analyses for kale rather than a true result. This is unfortunate as it makes it impossible to draw conclusions on the most appropriate management to maximise production of digestible biomass and further research will be needed.

Conclusions

- The total yield of kale crops was greatest when they were not defoliated.
  - Kale grew from sowing at 8.0 kg DM/ha per °Cd.

  - Earlier sowing dates and warmer environments give higher yields.
  - Leaf yield had a ceiling of 3.1 t DM/ha (1620 °Cd after sowing) with any subsequent production coming from stem.
- Defoliation reduced total yields but could increase leaf production
  - Kale regrew from defoliation at 5.3 kg DM/ha per °Cd.
  - Defoliation after ceiling leaf yield gave 0.9 – 1.4 t DM/ha additional leaf regrowth.
  - Defoliation at 10 cm gave greater yields than higher defoliations.
  - Kestral and Grunner had the same regrowth potential.

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