Nitrogen balance of kale

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Abstract

Kale is an important winter forage crop. It has a high requirement for nitrogen (N), but too much N can have adverse effects on animal health and create an environmental risk of N losses during grazing. N uptake and distribution during growth were studied to determine the N balance of a kale crop. Five N treatments were applied to an intensively-managed crop, and leaf and stem biomass and N content were measured regularly. Yields were high (up to 23,000 kg/ha) and did not respond to the N treatments because soil N fertility was high. However, N uptake was increased by N application, with a maximum uptake over 500 kg/ha. Leaf area expansion was not affected by the N treatments. However, leaf area declined faster in lower N treatments because leaves senesced as N was moved to the rapidly-growing stems and the plants maintained a minimum N content per unit leaf area in the remaining leaves. The results show that adequate N is needed later in crop growth to maintain leaf which is the crop component with the highest nutritional quality. On the other hand, late N increases risks of adverse animal and environmental effects.

Keywords

forage brassica, nitrogen uptake, nitrogen loss, environmental risk, kale model

Introduction

Kale is a forage brassica crop that is grown widely as a supplementary winter feed in New Zealand's pastoral systems. It is sown in early summer and grazed between late May and mid July. Kale has a high nitrogen (N) requirement, so good N availability is necessary for high yields. However, too much N can cause problems. Besides possible adverse health effects on grazing animals, there is an environmental risk of N losses from urine patches during grazing that is increasing as animal production systems intensify. We are adding relevant aspects of the N balance to a kale model (Wilson et al., 2004; Zyskowski et al., 2004) so it can be used as a tool for minimising N losses while also maintaining high productivity. As part of the project, we investigated N uptake and distribution during growth of an intensively-managed kale crop in a field experiment at Lincoln, New Zealand in 2005-06.

Methods

'Gruner' kale was sown at 3.5 kg/ha on 9 November 2005 in a fertile, deep (>1.6 m), free-draining soil (Udic Ustochrept, USDA Soil Taxonomy). Soil mineral N at sowing was high (257 kg/ha to 1 m depth). The crop was managed using best practices for kale to minimise limitations to growth. Base P, K, S and B fertiliser was applied before sowing. A total of 230 mm of water was applied in seven irrigations. Along with 270 mm of rainfall, this was enough to minimise yield reductions caused by water deficit. Pests were controlled with five insecticide applications, weeds were controlled with herbicides and there were no disease problems.

There were five N fertiliser treatments (Table 1) in a randomised complete block design with four replicates. Plot size was 10.0 x 3.4 m. In treatment 1 all N was applied at sowing, in treatment 2 33% was applied at sowing and the rest six weeks later, and in treatments 3 and 4 20% was applied at sowing and 40% at six and 12 weeks later. Samples were taken from the crop seven times, at intervals of about three weeks between 22 December and 9 May. Each time, plants were removed from a 1 m^2 area in each plot. They were counted, and the dry weights and N contents of leaf and stem components were measured. The area and dry weight of leaf samples were also measured. The results were analysed to obtain time courses of biomass production and N uptake, distribution of N and biomass, N content per unit leaf area and leaf area index (LAI).

Results

Establishment was excellent and the crop grew rapidly to produce a high yield. The initial population of about 60 plants/m^2 decreased by mid-January to a stable 45 plants/m^2 and was similar thereafter for all treatments. From December to May the growth rate averaged just over 150 kg/ha/day, and the peak rate was about 230 kg/ha/day during a three-week period in February-March. The N treatments had little effect on leaf and stem biomass production. Leaf biomass grew to a maximum of about 4,400 kg/ha by mid-February in all treatments, and then maintained that level as production of new leaves was matched by sensecence of old leaves. The only difference occurred near the end of growth, in April-May, when loss of leaf biomass occurred in treatments 1, 2 and 3 (Table 1). Stem biomass grew linearly to about 19,000 kg/ha and total biomass reached almost 23,000 kg/ha, with no differences among treatments.

Table 1. Total N fertiliser application, leaf biomass in early May 2006 and stem, leaf and total N uptake in mid April 2006, and N content per unit leaf area in early May in the five fertiliser treatments.

Treatment	N applied (kg/ha)	Leaf biomass (kg/ha)	N uptake (kg/ha)			N content per unit leaf area
			Stem	Leaf	Total	(g/m^2)
1	0	3400	177	86	263	1.60
2	50	3280	129	80	209	1.46
3	150	3040	186	102	288	1.90
4	250	4430	292	136	427	1.87
5	500	4480	383	140	523	2.09
LSD (P=0.05)	--	1495	103	38	96	0.44

Uptake of N was high and differed among the treatments. Total N uptake was highest in treatments 4 and 5 (Figure 1). It increased until mid-March and reached a maximum of over 500 kg/ha in treatment 5. Stem N uptake increased progressively and was highest in treatments 4 and 5 (Table 1). The N treatments did not affect the expansion of leaf area. LAI reached an average of 5.8 in all treatments in mid-February. Leaf N uptake, and therefore leaf N content per unit ground area, was highest in treatments 4 and 5 in mid-season, reaching a maximum of just over 200 kg/ha in March. After that it declined in all treatments because leaf N content, area and biomass all decreased as leaves senesced and N was moved to the rapidly-growing stems. The decline of leaf N was greater in the lower N treatments so that, by mid-April, it ranged from 80 to 140 kg/ha (Table 1). These decreases occurred to maintain a minimum N content per unit area in the remaining leaves so that it varied over a small range by early May (Table 1).

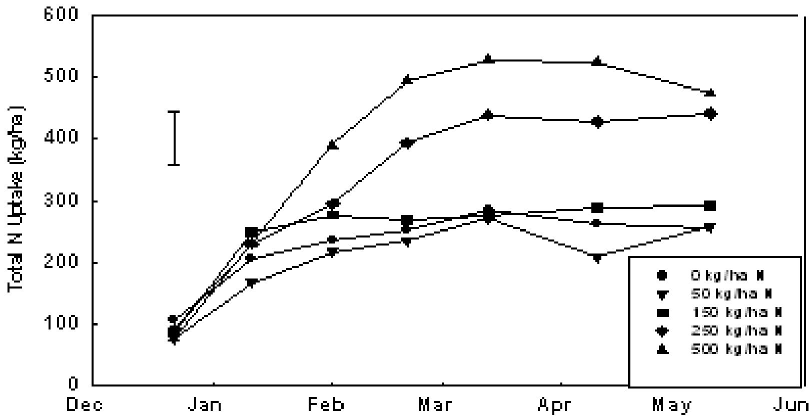

Figure 1. Total N uptake by kale in the five N fertiliser treatments. The vertical bar is the interaction 5% LSD with 65 df. See text and Table 1 for details of the treatments.

Conclusions

Soil N fertility was high so the N treatments had no effect on crop growth and yield. However, the treatments increased the N content of leaves and stems, possibly to levels that could be dangerous for grazing animals. In lower N treatments the crop maintained a minimum N content per unit leaf area, both through reduced leaf area and N allocation to stems. The results have implications for N management of kale, especially in intensively-managed crops with high yields. They indicate that adequate N is needed later in crop growth to maintain leaf biomass which is the crop component with the highest nutritional quality. On the other hand, late N increases risks of adverse animal and environmental effects.

References

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