The effect of delayed fertilizer N application on root biomass and N uptake of *Lolium perenne*

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Abstract

During the first days after harvest of *Lolium perenne* L., low N uptake from the soil may lead to N loss if N fertilizer is applied too soon. Furthermore, temporary N deprivation has been found to stimulate root growth. We therefore hypothesized that a strategic delay in N application after harvest may improve N use efficiency of *L. perenne* grassland by increasing root biomass and reducing N loss. In a laboratory and field experiment, we delayed N fertilizer application for 0, 3, 6, 9 and 12 days after harvest, and determined effects on herbage yield, herbage N uptake and root biomass of *L. perenne*. In both experiments, delaying N application with up to 12 days had no significant effect on root biFomass or total herbage N uptake. In the field experiment, total yield tended to be highest with a 3-day delay. For two harvests in the field experiment there was a significantly higher N uptake when N application was delayed, possibly due to rainfall-induced N losses in the treatments with shorter delay. Therefore, timing of N fertilizer application based on rainfall forecasts can contribute to improve N use efficiency by reducing N losses.

Keywords: N fertilization, delayed N application, root biomass, N use efficiency

Introduction

Strategic timing of N fertilizer application after cutting could be a valuable management tool to reduce N loss and increase N use efficiency of grassland, by synchronizing N supply with N demand. Various experiments have shown that during the first days of regrowth, most of the N comes from remobilized organic N stored in the stubble and roots, and that current root uptake of fertilizer N is low (Ourry *et al.*, 1989). Low uptake of fertilizer N during the first week after application increases the risk of N loss to the environment, especially with heavy rainfall. Additionally, there is evidence that temporary lack of N after harvest may stimulate root growth (Ennik and Hofman 1983; Jarvis and Macduff 1989). A higher rooting density and depth play a critical role in the interception and uptake of N by grass. The objective of the present study was to assess the effect of delaying N application after harvest on root biomass, herbage N uptake and herbage yield of *Lolium perenne* in a laboratory and field experiment. We hypothesized that temporary N deprivation by delaying N application after a harvest event may increase root biomass of *L perenne* resulting in increased N uptake and possibly also herbage yield.

Materials and methods

In the laboratory experiment, undisturbed *L. perenne* grassland soil cores (40 cm depth, 11.5 cm diameter) were placed in a controlled growth room. The grass was cut every 21 days, resulting in four harvests. N fertilizer application (100 kg N ha^{-1} cut^{-1}) was delayed for either 0, 3, 6, 9 or 12 days after each cut. Every four days a 10 mm rainfall event was simulated.

In the field experiment, we tested the same N delay treatments as in the laboratory experiment. The field experiment had a randomized block design with six replicate plots (10×2.5 m) in six locations (blocks) of permanent *L. perenne* grassland on a drought-sensitive sandy soil. The experiment included six harvest cycles (growth periods), with 4 to 6 weeks between each harvest. Total N application was 320 kg N ha^{-1} yr^{-1}. No irrigation was given.

In both experiments, herbage yield and N uptake were determined by cutting the grass to 6 cm height and measuring DM weight and N content. Roots were sampled after the final harvest. In the laboratory experiment, all roots per core per layer of 10 cm depth (0-10, 10-20, 20-30 and 30-40 cm) were sampled. In the field experiment, roots were sampled by taking three soil cores (8.5 cm diameter) from three soil layers (10-20, 20-30 and 30-40 cm depth, excluding 0-10 cm depth) in each plot. All soil cores were carefully washed through a 2 mm mesh screen and oven-dried at 70 °C for 24 hours to determine root biomass.

Results and discussion

In contrast to our hypothesis, delayed N application had no significant effect on total root biomass. A significant treatment effect on root biomass was only found for the 20-30 cm soil layer in the field experiment ($P<0.05$, Figure 1). In the experiments by Ennik and Hofman (1983) and Jarvis and Macduff (1989), treatments consisted of controlled interruptions of a continuous N supply to grass grown in nutrient solution, whereas in our experiments, N was supplied only at the start of each growth period. In our experiments it is possible that applied N was depleted before the next harvest and that in some cases all delay treatments may have experienced N shortage, masking effects of delayed N application on root biomass.

In the laboratory experiment, total herbage yield (cumulative over all harvests) was highest after a 3-day delay and was significantly reduced when N application was delayed by 6 days or more, with lowest yields observed after a 12-day delay (Table 1). A similar, though non-significant trend, was observed for total herbage yield in the field experiment (Table 1). This difference in significance may be explained by the shorter harvest cycles in the laboratory experiment (three weeks) compared to the field experiment (four to six weeks), which potentially increased the impact of delayed N application on herbage yield by reducing the opportunity for conversion of N into biomass in the former.

In the laboratory experiment, total herbage N uptake ranged from 247 to 304 kg N ha^{-1} (Table 1), and was not significantly affected by delaying N application. Similarly, in the field experiment, no significant effect of delay treatments on total herbage N uptake was detected (Table 1). However, when analysing the data for individual growth periods, we found that N uptake during the fourth and fifth period in the

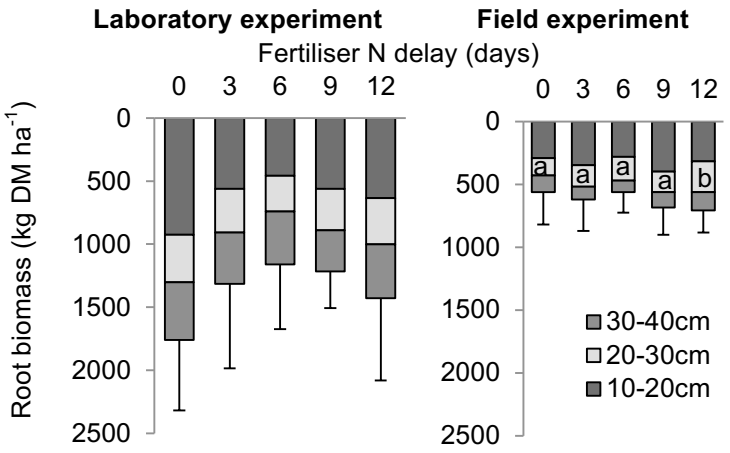

Figure 1. Mean *Lolium perenne* root biomass (kg DM ha^{-1}) in soil layers 10-20, 20-30 and 30-40 cm, as affected by delaying N application after harvest with 0, 3, 6, 9, or 12 days. Error bars represent standard errors of total root biomass (soil layer 10-40 cm). Different letters in treatment means within a soil layer indicate a significant difference (least significant difference 5%).

Table 1. The effect of delayed N application (0, 3, 6, 9 or 12 days) on herbage dry matter yield (dry matter yield (DMY), ton dry matter ha^{-1}) and N uptake (kg N ha^{-1}) in the laboratory and field experiment.[1]

	Laboratory experiment		Field experiment					
Delay	**DMY**	**N uptake**	**DMY**			**N uptake**		
(days)	Total[2]	Total	H4	H5	Total[2]	H4	H5	Total
0	18.7^{cd}	247	1.7	1.4^{a}	11.1	46^{a}	39^{a}	224
3	19.8^{d}	290	1.8	1.6^{b}	11.4	46^{a}	49^{b}	239
6	15.7^{bc}	277	1.8	1.5^{b}	11.1	48^{a}	47^{b}	238
9	15.1^{ab}	298	1.8	1.5^{ab}	10.7	51^{ab}	48^{b}	236
12	12.1^{a}	304	2.0	1.5^{b}	10.5	59^{b}	50^{b}	241
LSD[3] (P<0.05)	3.5	52	275	0.13	8.25	8	6	25
P-value	<0.01	0.19	0.11	0.04	0.18	0.01	0.01	0.65

[1] Different letters within a column indicate a significant (P<0.05) difference between treatments.

[2] Cumulative across 4 harvests for the laboratory experiment and 6 harvests for the field experiment; H4 = harvest 4; H5 = harvest 5.

[3] LSD = least significant difference.

field experiment was significantly higher (P=0.01) in plots where N application had been delayed with 12 days (fourth growth period) or 3 days or more (fifth growth period) (Table 1). This was probably related to rainfall patterns during the first 12 days of these growth periods. The significantly higher N uptake after N application delay of 9 to 12 days in the fourth period of the field experiment was associated with avoidance of N losses through leaching, high levels of rainfall occurred on day 6, 8 and 10 of that period. Similarly, the positive delay effect in the fifth period was associated with heavy rainfall on day 1 during that period. The apparent relatively large effects of rainfall events on herbage N uptake and herbage yield observed in our experiment suggest that delay of fertilizer N application can be used as a tool to increase N use efficiency and herbage yield of grassland by minimizing the risk of fertilizer N leaching.

Conclusions

In our experiments, a delay in N application of up to 12 days after harvest had no significant effect on *L. perenne* root biomass or total N uptake, but did significantly reduce total herbage yield in the laboratory experiment. The observed positive effects of delayed N application on N uptake and herbage yield in the fourth and fifth growth period in the field experiment appear to be the result of the avoidance of leaching, caused by heavy rainfall shortly after fertilizer N application. This suggests that strategic timing of N application based on rainfall forecasts could contribute to reduce N losses from leaching.

References

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