BIOLOGICAL NITROGEN FIXATION IN A GRASS-CLOVER PASTURE GRAZED BY DAIRY COWS

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ABSTRACT

The objective of this study was to estimate the annual input of nitrogen through biological nitrogen fixation (BNF) to a grass-clover pasture (*Lolium perenne* L. - *Trifolium repens* L.) grazed by dairy cows. The input was estimated by combining measurements of BNF in non-grazed plots, BNF in urine affected plots and estimates of the proportion of the pasture affected by urine. Total BNF in non-grazed plot was 75 and 256 kg N ha^{-1} in 1994 and 1995, respectively. Urine affected BNF both by decreasing the proportion of clover and by decreasing the proportion of N derived from the atmosphere. The average annual reduction in BNF in the grazed pasture due to animal urination was estimated to 14-21%.

KEYWORDS

N-fixation, ^{15}N dilution method, urine, white clover, ryegrass

INTRODUCTION

The biological nitrogen fixation (BNF) in grass-clover pastures is affected by a number of biotic and abiotic factors of which the soil N status is considered to be the primary factor (Ledgard and Steele, 1992). Grazing cattle return, in their excreta, a large proportion of the N ingested in herbage. Typically 75 to 95% of the ingested N is returned in dung and urine, with the latter accounting for approximately 75% of the N excreted (Afzal and Adams, 1992). During grazing, therefore, herbage N is removed from the total area and much of it is returned in excreta to localized areas at rates of up to an equivalent of 1200 kg N ha^{-1}, resulting in a high spatial variability of the soil N.

In the present investigation BNF was estimated in a grazed clover-grass pasture based on measurements of BNF in non-grazed plots and in simulated urine patches.

MATERIALS AND METHODS

In 1994 and 1995 BNF were estimated in a 1st and a 2nd year grass-clover, respectively. Measurements of BNF in non-grazed grass-clover were made in 1-m^2 plots outside the pasture, using the ^{15}N-dilution technique described by McNeil and Wood (1990). In the beginning of the growing season, about April 1st, labelled fertilizer solution (12.4 atom % $(^{15}NH_4)_2SO_4$) was applied at a rate equivalent to 20 kg N ha^{-1} to both grass-clover plots and grass only plots. The plots with grass only were used in calculating the proportion of N in clover derived from the atmosphere (pNdfa). The ^{15}N-plots were harvested 5-6 times during the growing seasons from April to October.

The effect of urine on the BNF was measured in simulated urine patches using the 15N-dilution technique. High-N (11.7 g total-N l^{-1}) and low-N (6.2 g total-N l^{-1}) urine, collected during milking from cows receiving either 310 or 140 g N day^{-1} cow^{-1} in the supplement, was applied (4.2 L m^{-2}) together with 4.7 g $(^{15}NH_4)_2SO_4$ L^{-1}. In the control treatment, water was used instead of urine.

Predicted proportion of the pasture affected by urine was determined according to Afzal and Adams (1992), who found that the area affected by urine after 120 grazing days with an animal density of 3.0 cows ha^{-1} was 17%. This corresponds to a daily increase in area affected by urine of 0.047% cow^{-1}, which was used together with the actual animal densities.

RESULTS AND DISCUSSION

A poor establishment of the clover (<10% clover until the month of July) resulted in relatively low nitrogen fixation rates for the 1994-season, even in the unaffected plots (Table 1). In 1995, with the proportion of clover ranging from 40 to 77%, the BNF was considerably higher. The urine affected BNF both by reducing the proportion of clover and by reducing the proportion of clover-N derived from the atmosphere (Fig. 1). Proportion of clover decreased from about 63% to 37% during a 2-month period after urine application. Similarly, the pNdfa dropped from about 0.9 to 0.3 during the first month after urine application. No difference between high-N and low-N urine was found. As an average over two months after urine application the pNdfa was reduced by 56%. Using the acetylene reduction method Søegaard *et al.* (1996) found that the N-fixation (nitrogenase activity) was reduced for at least 30 days after urine application, and the average reduction over this period was 64%. Similarly Ball *et al.* (1979) and Ledgard *et al.* (1982) found that the BNF within urine affected areas declined by up to 90%, and that the fixation activity recovered after 30-60 days, when soil inorganic N dropped to background level.

By including estimates of proportion of the area affected by urine as described by Afzal and Adams (1992) and the 56% reduction in pNdfa and the 59% reduction in proportion of clover found in the present investigation, the total above ground N-fixation was estimated to 59 and 220 kg N ha^{-1} in 1994 and 1995, respectively (Table 1). This corresponds a 14-21% reduction in the total N-fixation in the pasture due to animal activity, which is slightly lower than the 24% reduction estimated by Ledgard and Steele (1992) in an intensive dairy farm. By raising the actual animal density from 4.8 cows ha^{-1} (Table 1) to 6 cows ha^{-1}, the annual reduction in BNF will be 17-27%.

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Table 1
Dry matter production (DM), proportion of clover (Pro.cl.) and biological nitrogen fixation (BNF) in unaffected and urine affected grass-clover as well as animal density (AD), proportion of area affected by urine (Pro.u.), and biological nitrogen fixation in the grazed pasture.

		Unaffected		Urine affected		Pasture		
Date	DM, kg ha^{-1}	Pro.cl., %	BNF, kg N ha^{-1}	Pro.cl., %	BNF kg N ha^{-1}	AD, cows ha^{-1}	Pro.u, %	BNF, kg N ha^{-1}
				-------1994-------				
01.04	-	-	-	-	-	-	-	-
19.04	500	2.9	-	1.7	-	-	-	-
16.05	805	3.4	1.3	2.0	0.3	5.3	3	1.3
30.05	600	4.5	0.9	2.6	0.2	3.8	7	0.9
23.06	1018	9.9	2.8	5.8	0.8	3.8	13	2.6
19.07	1048	33.5	8.8	19.7	2.3	4.9	22	7.9
10.08	1318	43.6	19.8	25.6	5.2	4.9	28	16.2
15.09	1287	55.0	24.7	32.3	6.6	3.7	36	18.8
10.10	800	50.0	16.7	29.4	4.6	3.7	41	12.0
Total	7376		75.0		20.0			59.4
				-------1995-------				
01.04	-	-	-	-	-	-	-	-
20.04	500	40.0	9.1	23.5	2.5	-	-	9.1
23.05	1323	46.1	25.8	27.1	7.1	6.1	6	25.5
16.06	2717	51.1	58.2	60.0	15.7	6.5	14	53.8
19.07	3274	77.0	76.6	45.2	20.3	6.5	25	65.1
17.08	1422	70.1	51.6	41.2	13.6	4.2	31	41.1
10.10	1299	64.0	34.3	37.6	9.4	4.0	42	25.3
Total	10535		255.6		68.6			219.9

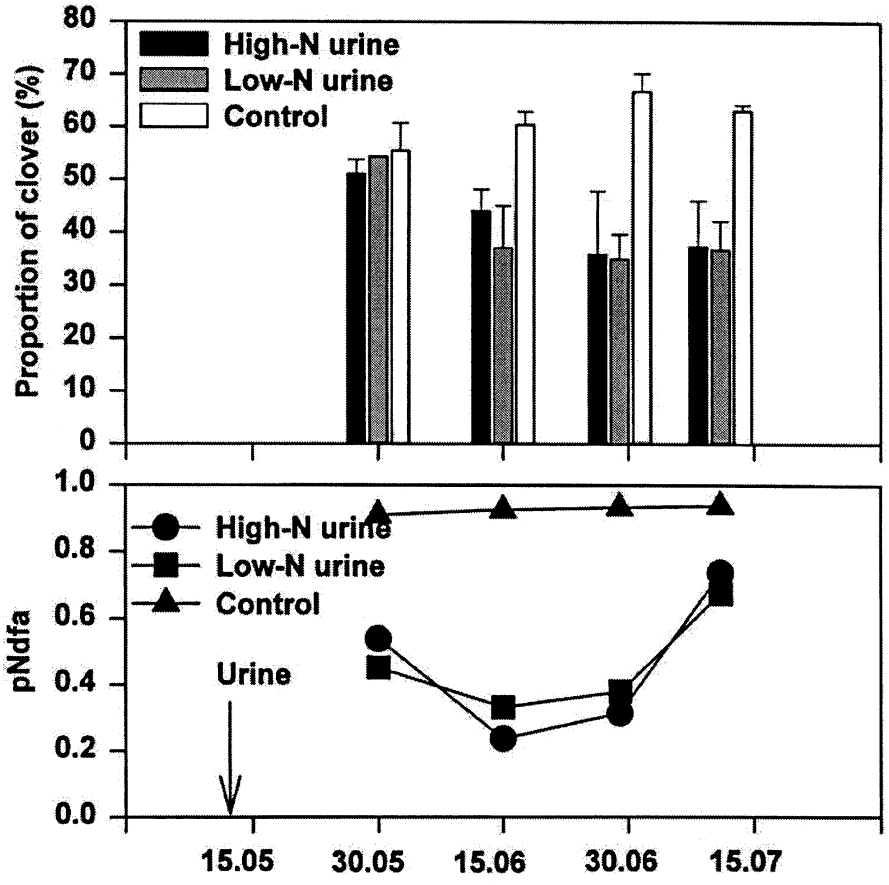

Figure 1.
Proportion of clover and proportion of N derived from the atmosphere (pNdfa) after urine application to grass-clover.