NITROGEN FLOWS AND USE EFFICIENCY IN A GOLF GREEN DURING THREE SEASONS IN CENTRAL SWEDEN

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Few studies have been carried out on the influence of organic matter content on the flows of nitrogen in a golf green, especially in cold temperate climates. A study was set up in central Sweden, to follow some of the expected nitrogen flows in a golf green, *e.g.* nitrogen leaching, nitrogen removal with the grass clippings and nitrogen stored in the soil, and to calculate nitrogen balances. *Agróstis stolonífera* was grown in sand dominated rootzone mixtures with different contents of organic matter (2 to 4%). Nitrogen was added as NH_4NO_3 with a total application of about 2 kg 100 m^{-2} per season (April to October).

Sampling was carried out during three 14 day fertilisation cycles in 2001, 2002 and 2003. The sampling dates were selected to cover the beginning, the middle and the end of each season. Drainage water was collected either daily, or every second day, with flow rates measured by a tipping bucket device. The drainage water was analysed for NH_4, NO_3, and total N (2003 only). Biomass production was measured either daily, or every second day, by collecting grass clippings. The grass clippings were analysed for total nitrogen. Soil samples were collected at 1.5-30 cm depth on the first and last day of each fertilisation cycle, and available nitrogen in the soil was extracted and analysed.

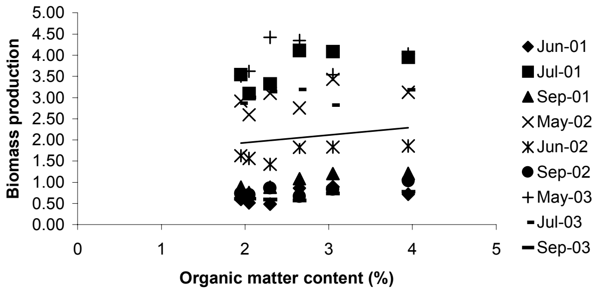

Figure 1. Total biomass production (kg dry material 100 m^{-2}) for each sampling period and organic matter content in the rootzone mixture. The biomass production shows a positive correlation (p=0.0002) with the organic matter content. The central line shows the mean function for all sampling periods (y=1.57+0.1804x).

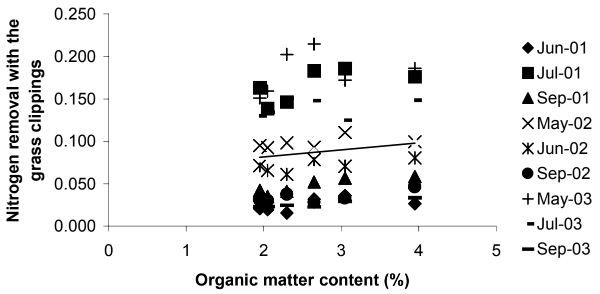

Figure 2. Total nitrogen removal with the grass clippings (kg N 100 m^{-2}) for each sampling period and organic matter content in the rootzone mixture. Nitrogen removal shows a positive correlation (p=0.0006) with the organic matter content. The central line shows the mean function of the correlation for all sampling periods (y=0.065+0.0083x).

Statistical analysis, ANOVA and step-wise multiple linear regression by the repeated use of the General Linear Model procedure (GLM) of the SAS statistical package, showed that the time of sampling was the dominant factor explaining 96.8 % of the variations in biomass production (Figure 1). However, the inclusion of organic matter in the statistical model showed that biomass production was also positively and significantly correlated with the amount of organic matter in the rootzone (p = 0.0002) and this increased the r^2 value to 0.977 (Figure 1).

The nitrogen concentration in the grass was fairly constant (on average 4.5 % and a standard deviation of 0.46, n=461), so nitrogen removal showed the same trends as biomass production (Figure 2). Similar to biomass production, nitrogen removal was positively and significantly (p = 0.0006) correlated with the organic matter content in the rootzone. The time of sampling was still the dominant factor controlling the variations but the inclusion of organic matter in the statistical model increased the r^2 value from 0.962 to 0.971 (Figure 2).

The large differences in biomass production between the different sampling occasions may be attributed to environmental factors such as temperature and light. At high latitudes as in Scandinavia, light limits growth late in the season while temperature is often the more limiting factor in the spring. In our study, biomass production declined dramatically in the September sampling in all three years, while the May-June samplings showed a more variable cumulative biomass production, which strongly depended on the soil temperature sums above 4%C in each year (Figure 3).

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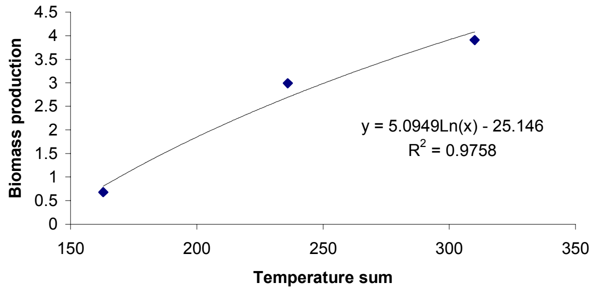

Figure 3. Total 14-day biomass production in May/June samplings (mean of 6 treatments) correlated with the sums of daily mean temperature exceeding 4°C from March 15 until the first sampling date.

The nitrogen lost by leaching was largest in June 2001, in September 2001 and in May 2003, and was very small throughout 2002. In relation to the nitrogen added as fertiliser, on average 8.7 %, 0.6 % and 3.2 % was leached (as nitrate and ammonium) in 2001, 2002 and 2003 respectively. When organic N was also analysed in the leachate (in 2003) total nitrogen leaching proved to be as much as 9 % of the added nitrogen (Table 1). Leaching was smallest at times in the season with high biomass production, except in May 2003.

Measured mass balances showed that removal with the grass clippings was the largest nitrogen flow (between 15-102 % of the nitrogen added) and its magnitude strongly influenced other important nitrogen flows, such as leaching (Table 1). Values higher than 100 % imply that mineralisation of organic N provided additional nitrogen for uptake by the grass. The very low nitrogen use efficiencies in June 2001 (15 %) and September 2002 (20 %) resulted in amounts of nitrogen that could not be accounted that were within the range of the nitrogen added (Table 1). Large nitrogen losses and low values of NUE were found in the beginning of 2001 and at the end of all seasons, which again indicates that potential biomass production was limited by sub-optimal temperature in spring, and sub-optimal light conditions in autumn.

Table 1. Mass balances of the nitrogen flows (kg N 100 m^{-2}) measured for each sampling period. The mass balances are calculated for an interpolated value (from regression analyses) of nitrogen removal with the grass clippings at 3 % organic matter content in the rootzone mixture

Treatment:	2001			2002			2003		
	June	July	September	May	July	September	May	July	September
Input									
Fertiliser[1]	0.18	0.18	0.07	0.18	0.18	0.18	0.18	0.18	0.05
Output									
Grass clippings	0.027	0.171	0.051	0.099	0.073	0.037	0.184	0.141	0.028
Leaching to drains[2] (NH_4 and NO_3)	0.016	0.004	0.0107	0.0006	0.002	0.0008	0.009	0.001	0.002
Leaching to drains[2] (Total N)	-	-	-	-	-	-	0.024	0.008	0.005
Storage balance									
Δ soil mineral N[3]	-0.041	0.016	-0.001	0.104	0.070	-0.054	-[4]	0.005	-0.024
N not accounted for[5]	0.178	-0.01	0.009	-0.02	0.035	0.19	-0.03[6]	0.026[6]	0.04[6]
NUE[7] (%)	15	95	72	55	40	20	102	78	56

1 Information from the course superintendent

2 Mean value (n=2)

3 Mean value (n=6) calculated as N content day 14 - N content day 0

4 Missing value

5 Mass balance calculated as nitrogen added = nitrogen leached to drains+ nitrogen removed with grass clippings + Δ store of available nitrogen in the soil + [nitrogen not accounted for]

6 Total N in the leachate used

7 NUE = (Σ nitrogen in the grass clippings/Σ nitrogen addition by fertilisation) x 100.