Nitrate content of soil water under forage crops fertilised with dairy slurry in nitrate vulnerable zone

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Abstract

Three contiguous plots established on highly permeable soil in the Po valley (Italy), and equipped with tensiometers and ceramic cup samplers, have been cropped respectively with lucerne (Medicago sativa), tall fescue (Festuca arundinacea), and their mixture. Dairy slurry was applied three times during the second year (at the end of the winter and after the 1st and 4th cut), with total amounts of 272 kg N ha⁻¹ for tall fescue and 136 kg N ha⁻¹ (half rate) for the mixture. Lucerne was not fertilised with nitrogen.

Total yields for the 5 cuts were 17.8 t DM ha⁻¹ for lucerne (average protein content 18.2 % DM), 10.9 for tall fescue (protein 12.6 % DM) and 19.2 for the mixture (protein 17.0 % DM). Soil water nitrate content was steadily low under each of the three forage crops, with average values ranging from 5 (tall fescue plot) to 10 (lucerne plot) mg NO₃-N l⁻¹, without significant negative impact on groundwater. Activities are currently being carried out to verify the effect of repeated application rates higher than the 170 kg N ha⁻¹ year⁻¹ limit fixed for NVZ in Nitrate Directive 91/676.

Keywords: ceramic cups, dairy slurry, lucerne, tall fescue, Nitrate Vulnerable Zones (NVZ).

Introduction

The Nitrate Directive 91/676 fixes the maximum limit for manure application at 170 kg N ha⁻¹ year⁻¹ in Nitrate Vulnerable Zones (NVZ). The use of mineral fertilisers is not subject to the same limit. It seems reasonable to argue that manure can be applied in excess of the value of 170 kg N ha⁻¹ year⁻¹ in dairy farms with extensive areas of grassland, without a significant increase in nitrate leaching. Data from different trials confirmed that on normal productive cut grassland, also after incorporation of long-term effects, total nitrogen amounts of cattle slurry up to 400 kg N ha⁻¹ year⁻¹ have very little effect on residual mineral nitrogen in autumn, if not accompanied by high mineral fertiliser doses (Ten Berge et al., 2002).

The main purpose of this study is to evaluate nitrate leaching from leys on highly permeable soil in NVZ in the Po valley (Italy).

Materials and methods

In the spring of 2005 three different swards of lucerne (Medicago sativa), tall fescue (Festuca arundinacea) and a mixture of the two were established on three contiguous 50 x 30 m plots on a loamy skeletal, mixed, mesic Udic Haplusterts which had been fertilised with farmyard manure at the rate of 175 kg N ha⁻¹ in October 2004. Each plot was equipped with 6
tensiometers to measure soil potential at depths of up to 180 cm and 9 ceramic cup samplers to collect soil water in depths of up to 500 cm. No fertilisers have been applied nor forage crops harvested over 2005. The three plots were managed as specified in Table 1 over the following year.

<table>
<thead>
<tr>
<th>Data</th>
<th>Activities</th>
<th>Application rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 March 2006</td>
<td>Dairy slurry application</td>
<td>90 kg N ha⁻¹ *</td>
</tr>
<tr>
<td>12 May 2006</td>
<td>1st cut</td>
<td></td>
</tr>
<tr>
<td>23 May 2006</td>
<td>Dairy slurry application</td>
<td>106 kg N ha⁻¹ *</td>
</tr>
<tr>
<td>15 June 2006</td>
<td>Irrigation</td>
<td>80 mm</td>
</tr>
<tr>
<td>22 June 2006</td>
<td>2nd cut</td>
<td></td>
</tr>
<tr>
<td>08 July 2006</td>
<td>Irrigation</td>
<td>80 mm</td>
</tr>
<tr>
<td>17 July 2006</td>
<td>3rd cut</td>
<td></td>
</tr>
<tr>
<td>28 August 2006</td>
<td>4th cut</td>
<td></td>
</tr>
<tr>
<td>06 September 2006</td>
<td>Dairy slurry application</td>
<td>76 kg N ha⁻¹ *</td>
</tr>
<tr>
<td>13 October 2006</td>
<td>5th cut</td>
<td></td>
</tr>
</tbody>
</table>

*: application rate for tall fescue, half-rate for tall fescue+lucerne, no slurry for lucerne

Dairy slurry (7% DM, 2.5 g TKN kg⁻¹) was applied three times, with total amounts of 272 kg N ha⁻¹ for tall fescue and 136 kg N ha⁻¹ (half rate) for the mixture. Lucerne received mineral phosphorus and potassium to compensate for the missing slurry input but was not fertilised with nitrogen. The plots were irrigated twice by a spray boom at 30 mm hour⁻¹. The three swards were harvested five times over 2006; herbage production was measured at each cut in areas the size of 2.5 x 5 m, with three replicates for each sward. Dry matter production and forage quality were determined (protein, fibre and ash content, NDF, ADF, ADL). Soil potential data were registered every 12 hours by electronic loggers connected with tensiometers. Soil water was sampled from ceramic cups to determine NO₃−N and NH₄−N concentrations every 3 weeks; sampling nearer the surface was limited by low soil potential values during the dry season. Soil samples were taken from each plot about every 3 months, the layer sampling (20 cm) reached a depth of 60 cm, with three replicates. Each sample was tested for NO₃−N concentration.

Results up to October 2006 are included in this paper.

Results and discussion

Average temperatures and rainfall during the January-October 2006 period are presented in Table 2. The matric potential of the soil remained near zero (value that corresponds to the presence of free water) up to April. From April onwards there was progressive drying of horizons interrupted sporadically by rainfall and irrigation, particularly for the 1 metre top layer.

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*: application rate for tall fescue, half-rate for tall fescue+lucerne, no slurry for lucerne

Figure 1 illustrates forage yields obtained in 2006 while Table 3 shows the average forage quality characteristics.
Figure 1. Dry matter yield for the five cuts

Table 3. Total dry matter yield and chemical characteristics of the forages (5 cuts average)

<table>
<thead>
<tr>
<th></th>
<th>Lucerne</th>
<th>Lucerne+ tall fescue</th>
<th>Tall fescue</th>
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<tbody>
<tr>
<td>Annual yield (t DM ha⁻¹)</td>
<td>17.8</td>
<td>19.2</td>
<td>10.9</td>
</tr>
<tr>
<td>Mean protein content (% DM)</td>
<td>18.2</td>
<td>17.0</td>
<td>12.6</td>
</tr>
<tr>
<td>Total N uptake (kg ha⁻¹)</td>
<td>518</td>
<td>520</td>
<td>218</td>
</tr>
<tr>
<td>Fibre content (% DM)</td>
<td>31.5</td>
<td>29.2</td>
<td>24.7</td>
</tr>
<tr>
<td>Ash content (% DM)</td>
<td>10.4</td>
<td>10.4</td>
<td>10.2</td>
</tr>
<tr>
<td>NDF (% DM)</td>
<td>49.1</td>
<td>50.3</td>
<td>58.5</td>
</tr>
<tr>
<td>ADF (% DM)</td>
<td>37.0</td>
<td>34.3</td>
<td>29.1</td>
</tr>
<tr>
<td>ADL (% DM)</td>
<td>8.0</td>
<td>6.7</td>
<td>3.6</td>
</tr>
</tbody>
</table>

Production was very good for lucerne and the mixture, both in quantity and quality, assisted by the rainfall in August and September and the mild temperatures maintained up to October. Tall fescue in the mixture was overwhelmed by lucerne after the first cut. Pure tall fescue production was clearly lower. This sward was not well established at the start of 2006 and it suffered from the heat and dryness of the first part of the summer. Probably it also suffered from lack of nitrogen as seems to be confirmed by the following data.

In Figure 2 changes in the nitrate nitrogen concentrations in soil water are illustrated for each plot according to the length of time (X-axis, 2 years) and the depth of the soil (Y-axis, 500 cm), through concentration isolines obtained from data interpolation.

Soil water nitrate content was constantly low under each of the three forage crops, with average values for 2006 ranging from 5 (tall fescue) to 10 (lucerne) mg NO₃-N l⁻¹, without significant negative impact on groundwater.

During the monitoring period, the NH₄–N concentrations in the soil water were always distinctly lower than NO₃–N values (with average values <0.2 mg l⁻¹ NH₄-N), as already verified in other trials (Mantovi et al., 2006).

The concentrations of nitrates in the soil were constantly low (average value of 6.5 mg NO₃-N kg⁻¹ in 2006) with no marked differences among the three swards. Over the summer of 2006 the lowest concentrations were found in the tall fescue plot even though slurry had been applied and forage production was poor (but in any case with quite good apparent recovery of nitrogen). In the same plot there was no accumulation of residual mineral soil nitrogen during the autumn (about 50 kg ha⁻¹ of soil NO₃–N in the 0-60 cm soil layer at the end of October).
Figure 2. Nitrate nitrogen concentration in soil water (mg NO\textsubscript{3}-N l\textsuperscript{-1}), for each plot

Conclusion

The results obtained confirm that forage crops, in particular some grasses fertilised with nitrogen from slurry applied at rates of more than 170 kg N ha\textsuperscript{-1} year\textsuperscript{-1}, are able to deplete nitrates in the soil and in the soil water in vulnerable soils. It is thus possible to qualify these crops as useful to protect groundwater from the infiltration of these pollutants. Activities are now being conducted to test the effect of repeated application rates significantly higher than the 170 kg N ha\textsuperscript{-1} year\textsuperscript{-1} limit fixed for NVZ in Nitrate Directive 91/676.

References