Effects of repeated dairy slurry applications on forage crops in a nitrate vulnerable zone of Northern Italy

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Abstract

In the spring of 2005 three different swards of lucerne (*Medicago sativa* L.), tall fescue (*Festuca arundinacea* Schreb.) and a mixture of the two were grown on three contiguous 30x50 m plots on highly permeable soil in the Po valley (Northern Italy). Each plot was equipped with tensiometers to measure soil potential at depths of up to 180 cm and ceramic cup samplers to collect soil water up to 500 cm.

Dairy slurry was applied three times during both 2006 and 2007 (at the end of the winter and after the 1st and 4th cut), with total amounts significantly exceeding the Nitrate Directive limit (about double) for tall fescue and close to the same limit for the mixture. Lucerne was not fertilised with nitrogen.

Five cuts were effected in 2006 and four in 2007. Production was very good for lucerne and the mixture, both in quantity and quality, for both years. Tall fescue in the mixture was overwhelmed by lucerne after the first cut. Pure tall fescue production was markedly lower.

Soil water nitrate content was steadily low under each of the three forage crops, with average values ranging from 5 (tall fescue plot) to 11 (lucerne plot) mg NO_3-N L^{-1}, without significant negative impact on groundwater quality.

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^{-1} $year^{-1}$, are able to deplete nitrates in the soil and in the soil water in vulnerable soils. Such crops can thus be qualified as useful in protecting groundwater from infiltration by these pollutants.

Keywords: ceramic cups, dairy slurry, forage crops, lucerne, Nitrates Directive, tall fescue.

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 (Northern Italy).

Materials and methods

In the spring of 2005 three different swards of lucerne (*Medicago sativa* L.), tall fescue (*Festuca arundinacea* Schreb.) and a mixture of the two were established on three contiguous 50 x 30 m plots on a *loamy skeletal, mixed, mesic Udic Haplustepts* 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 two years.

Table 1. Management of the three plots

Data	Cultural practices	Application rate
20 March 2006	Dairy slurry application	90 kg N ha^{-1} *
12 May 2006	1st cut	
23 May 2006	Dairy slurry application	106 kg N ha^{-1} *
12 and 17 June 2006	Irrigation	40+40 mm
22 June 2006	2nd cut	
04 and 11 July 2006	Irrigation	40+40 mm
17 July 2006	3rd cut	
28 August 2006	4th cut	
06 September 2006	Dairy slurry application	76 kg N ha^{-1} *
13 October 2006	5th cut	
09 March 2007	Dairy slurry application	130 kg N ha^{-1} *
23 April 2007	1st cut	
07 May 2007	Dairy slurry application	97 kg N ha^{-1} *
15 and 22 May 2007	Irrigation	45+50 mm
18 June 2007	2nd cut	
13 July 2007	3rd cut	
03 and 10 August 2007	Irrigation	60+60 mm
21 September 2007	4th cut	
30 September 2007	Dairy slurry application	107 kg N ha^{-1} *

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

Dairy slurry (average values of 7% DM, 2.5 g TKN kg^{-1} of which 45-50% NH_4–N) was applied three times during both 2006 and 2007 (at the end of the winter and after the 1st and 4th cut), with total amounts significantly exceeding the Nitrate Directive limit (about double) for tall fescue and close to the same limit 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 four times a year by a spray boom at 30 mm $hour^{-1}$. The three swards were harvested five times over 2006 and four times over 2007; 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 NO_3–N and NH_4–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 each) reached a total depth of 60 cm, with three replicates. Each sample was tested for NO_3–N concentration by ionic chromatograph.

Results up to September 2007 are included in this paper.

Results and discussion

Monthly average air temperatures and total rainfall are presented in Table 2 for 2006 and 2007. The matric potential of the soil remained near zero (value that corresponds to the presence of free water) up to April for both years. From April onwards there was progressive drying of horizons interrupted sporadically by rainfall and irrigation, particularly for the 1 metre top layer.

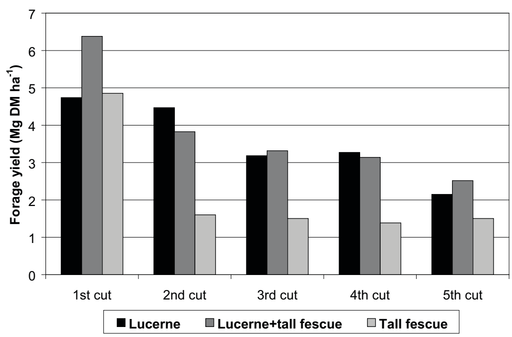
Table 2. Monthly average air temperature and total rainfall

2006	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Temperature (°C)	0.8	3.5	7.5	12.9	18.0	22.7	26.6	21.7	20.5	15.2	9.1	4.4
Rainfall (mm)	43.6	50.6	28.4	31.0	19.4	9.6	9.4	92.0	175.0	22.0	42.4	24.8

2007	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Temperature (°C)	6.0	2.0	14.2	27.8	25.5	27.8	32.4	29.4	25.7
Rainfall (mm)	23.8	56.4	134.6	21.8	49.4	72.8	1.0	22.4	33.4

Figure 1 illustrates forage yields obtained in 2006 and 2007 while Table 3 shows the average forage quality parameters.

Figure 1. Dry matter yield for the five cuts of 2006 and the four cuts of 2007



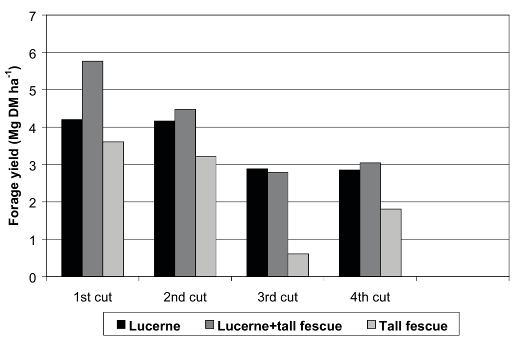


Table 3. Total dry matter yield and chemical composition of the forages

2006 (5 cuts average)	Lucerne	Lucerne+ tall fescue	Tall fescue
Annual yield (Mg DM ha-1)	17.8	19.2	10.9
Mean protein content (% DM)	18.2	17.0	12.6
Total N uptake (kg ha-1)	518.0	520.0	218.0
Fibre content (% DM)	31.5	29.2	24.7
Ash content (% DM)	10.4	10.4	10.2
NDF (% DM)	49.1	50.3	58.5
ADF (% DM)	37.0	34.3	29.1
ADL (% DM)	8.0	6.7	3.6
2007 (4 cuts average)	**Lucerne**	**Lucerne+ tall fescue**	**Tall fescue**
Annual yield (Mg DM ha^{-1})	13.0	14.7	8.6
Mean protein content (% DM)	17.3	15.7	11.2
Total N uptake (kg ha3 pt)	359.0	369.0	153.0
Fibre content (% DM)	31.8	32.3	27.1
Ash content (% DM)	9.8	10.1	10.4
NDF (% DM)	47.2	51.2	57.6
ADF (% DM)	38.4	38.6	32.4
ADL (% DM)	8.4	7.5	3.4

Production was very good for lucerne and the mixture, both in quantity and quality, especially in 2006 when assisted by the rainfall in August and September and the temperatures were mild up to October, permitting the 5^{th} cut. Both years, tall fescue in the mixture was overwhelmed by lucerne after the first cut and pure tall fescue production was clearly lower. Pure tall fescue sward was not well established at the start of the experiment and it suffered from the heat and dryness of the first part of the summer seasons. Probably it also suffered from lack of nitrogen as seems to be confirmed by the following data.

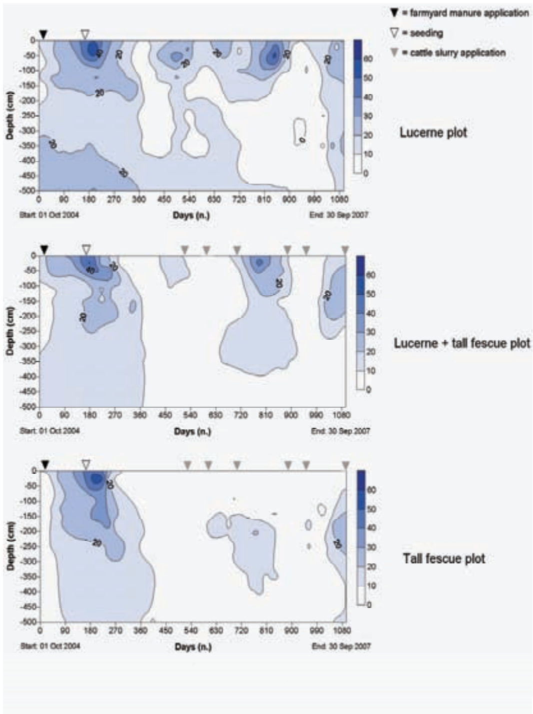
In Figure 2 changes in the nitrate nitrogen concentrations in soil water are illustrated for each plot according to the length of time (X-axis, 3 years) and the depth of the soil (Y-axis, 500 cm), through concentration isolines obtained from data interpolation (Surfer software).

Soil water nitrate content was constantly low under each of the three forage crops, with average values for the 2006-2007 period ranging from 5 (tall fescue) to 11 (lucerne) mg NO_3-N L^{-1}, without significant negative impact on groundwater quality.

During the monitoring period, the NH_4–N concentrations in the soil water were always distinctly lower than NO_3–N values (with average values <0.2 mg L^{-1} NH_4-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 NO_3-N kg^{-1} in 2006 and of 8.5 mg NO_3-N kg^{-1} in 2007) with no marked differences among the three swards. Over 2006 and 2007 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 uptake of nitrogen). In the same plot there was no significant accumulation of residual mineral soil nitrogen after the last cut (about 50 and 60 kg ha^{-1} of soil NO_3–N in the 0-60 cm soil layer respectively at the end of October 2006 and at the end of September 2007).

Figure 2. Nitrate nitrogen concentration in soil water (mg NO_3-N L^{-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^{-1} $year^{-1}$, are able to deplete nitrates in the soil and in the soil water in vulnerable soils. Such crops can thus be qualified as useful in protecting groundwater from infiltration by these pollutants.

Tests are currently being conducted to verify the long term effect of repeated applications at rates higher than the 170 kg N ha^{-1} $year^{-1}$ limit fixed for nitrate vulnerable zone in the Nitrates Directive 91/676 and to control the effects due to grassland renewal or ploughing.

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