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NITROGEN BUDGETS FOR THREE CROPPING SYSTEMS FERTILISED WITH CATTLE MANURE

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INTRODUCTION

Dry matter yields and N uptake have been correlated with the inorganic N applied in manure and therefore differences could be expected following application of slurry and farmyard manure (FYM). Most studies agree that manures with higher available N generally give higher DM yields (e.g. Pain, 2000).

There is a lack of comparative information regarding N utilisation and losses from manures with different dry matter contents, particularly comparative investigations of different cropping systems. The review of the literature has also highlighted significant differences in N utilisation by grass and maize crops, which are the most important crops used in dairy production in temperate areas, and where manures are commonly applied.

This study aimed to determine the N use efficiency of manures with different dry matter contents in three contrasting cropping systems. An additional aim of the study was to determine the relative losses of N to the environment and produce a N balance for the different manure on these cropping systems.

METHODS

A field plot experiment was set up on a sandy loam soil of the Crediton series, located near the Institute of Grassland and Environmental Research, North Wyke, SW England (50°45'N, 3°50'W).

The manure treatments were low (*c.* 3.5%) and high dry matter (*c.* 8.0% DM) cattle slurries and one farmyard manure (FYM, *c.* 20.0% DM). Manure application rate was targeted at 200 kg total N $ha^{-1}year^{-1}$. An untreated control was included for each rotation. There were three different cropping systems: ryegrass/clover mixture, maize/rye/maize and maize/maize. In the first year, manures were incorporated into the soil and in the second year were incorporated for the maize systems and surface applied for the ryegrass/clover system.

Measurements were made of N losses (ammonia volatilisation, denitrification, and nitrate leaching), N uptake and herbage DM yields. The study data was used to produce a N balance for the three cropping systems receiving manures. In addition, estimation of N fixation and N deposition were obtained from the literature (Campbell *et al*., 1988; Derwent *et al.*, 1988; Scholefield *et al.*, 1996). Nitrogen fixation values were modelled taking into account the reduction in fixation due to rates of NH_4^+-N applied from the different manure types.

RESULTS AND DISCUSION

A nitrogen balance for the different manure and cropping treatments are shown in Tables 1 and 2. In general, for the ryegrass/clover system, there was low or no response to the different manures at the rate of N applied, which was reflected in similar N uptakes obtained with the different manure treatments for each of the two years of this study. Nitrogen losses were independent of the manure type applied, with no significant differences between control and manure treated plots. Only when manures were surface applied to the grass sward (second year) were high N losses due to ammonia (NH_3) volatilisation observed as a direct consequence of manure applications. Under the experimental conditions, this management option showed the highest risk of N loss to the wider environment. This negative effect, however, could be significantly reduced using alternative application techniques, e.g. shallow injection.

The maize cropping systems, showed a large response to manure applications in both years. This was reflected also in the different N uptakes obtained from the slurry compared with the FYM treatments in the maize/rye system. An important management option that can explain, in part, the positive response to the different manures applied was the low or no NH_3 losses, which was achieved by a rapid incorporation of manures into the soil. On the maize/rye systems, N losses (volatilisation, leaching and denitrification) did not differ between the manure treatments and the untreated.

Cropping systems had a significant effect on the N balance (Tables 1 and 2). On the ryegrass and clover system, accumulation of soil N was observed, particularly in the manure treated plots. In contrast, the two arable cropping systems showed a negative N balance that implied a reduction in soil N. This was partially compensated by manure applications, which were unable to provide the total N removed through herbage offtake and lost via leaching and denitrification. In the arable systems, the highest losses were due to inorganic N leaching, which were largely affected by the cropping system itself, as there were similar losses observed in both treated and untreated plots.

Estimated nitrogen fixation constituted an important input of N to the soil in the ryegrass and clover sward averaging between *c.* 25% to 50% and *c.* 80% to 90% of the total N inputs for manure and control treatments, respectively. For the maize systems, inputs were principally atmospheric deposition of N and manure N on treated plots. Plant uptake of N represented the highest proportion of N outputs, varying from 58% to 98% of the total outputs per year.

An important difference between grass and maize systems is soil cultivation. Long-term experiments have shown that under permanent grass there is a continuous organic matter accumulation, contrasting with arable rotations where reductions of soil organic matter contents are observed (e.g. Shepherd *et al.*, 1996).

When comparing both arable systems, it was possible to observe that maize/rye had a higher N output than the maize/maize system, which suggests that the incorporation of a cover crop during winter resulted in greater use of the soil N than that observed with bare soil. This could be attributed to an increased mineralisation of the soil N, enhanced by autumn cultivation and the N uptake by rye. The application of manure in the arable systems compensated in part for the loss of soil N, particularly in the first year. However, in the second year due to higher maize yields there was a greater N deficit (*c.* 70 to 105 kg N ha^{-1} yr^{-1}).

This study found that the most efficient use of N could be achieved when manures were incorporated into the soil prior to maize drilling, combined with the use of a cover crop (rye) after maize harvest. This management option resulted in highest N uptakes and the lowest manure N losses between the three systems, especially when using slurries. However, analysing the maize/rye systems as a whole, e.g. taking into account losses from the untreated plots, higher N leaching losses were obtained than those observed in the ryegrass and clover system.

From an environmental perspective, the best option was achieved when manures where incorporated into the soil prior to spring establishment of the ryegrass and clover sward. This option resulted in the utilisation of manure N with the lowest N losses due to volatilisation, leaching and denitrification, which did not differ from those observed in the untreated plots.

Based on the experimental results from the present study, it is possible to conclude that in the short-term, manure applications based on adequate management practices generally did not result in higher N losses than untreated plots for the three systems. Only when manures were surface applied, NH_3 losses were influenced by the dry matter content of manures.

Cropping systems showed similar N recoveries, but significantly greater N losses (leaching and denitrification) were measured from the arable systems compared to the grass sward, where the inclusion of a cover crop (rye) after maize had a positive effect in reducing the N losses due to leaching.

Table 1. Nitrogen balance for the different manure and crop treatments 1998-1999.

1998 – 1999	**Ryegrass and clover**				**Maize / rye**				**Maize / maize**	
(kg N ha^{-1} yr^{-1})	Control	SLDM	SHDM	FYM	Control	SLDM	SHDM	FYM	Control	SHDM
INPUTS										
Manure N	0.0	179.3	204.1	193.1	0.0	176.7	206.4	177.9	0.0	205.8
N Fixation §	88.7	64.6	67.9	81.1	0.0	0.0	0.0	0.0	0.0	0.0
Atmospheric N ¥	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0
TOTAL INPUTS	**113.7**	**268.9**	**297.0**	**299.2**	**25.0**	**201.7**	**231.4**	**202.9**	**25.0**	**230.8**
OUTPUT										
NH_3 volatilisation	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0 #
Ni-N leaching	5.0	5.1	7.6	6.3	55.4	50.9	80.1	43.7	88.3	88.8
Denitrification	0.8	2.4	3.1	2.5	0.7¶	0.6¶	1.1¶	0.9¶	?	?
N uptake	102.9	138.1	132.1	132.8	167.9	196.5	187.7	168.3	101.6	124.1
TOTAL OUTPUTS	**108.8**	**145.6**	**142.8**	**141.6**	**224.1**	**247.9**	**268.8**	**212.9**	**189.9**	**212.9**
INPUTS-OUTPUTS	**4.9**	**123.3**	**154.3**	**157.6**	**-199.1**	**-46.2**	**-37.4**	**-10.1**	**-164.9**	**17.9**
s.e.	**(8.76)**	**(3.08)**	**(10.74)**	**(4.62)**	**(19.61)**	**(15.92)**	**(22.38)**	**(11.79)**	**(11.28)**	**(15.51)**

§ Estimated from NFIXCYCLE model considering the actual DM yields (Scholefield *et al.*, 1996).
¥ Estimated from values measured by Campbell *et al.* (1988) and Derwent *et al.* (1988).
Estimated from evaluations carried out on maize/rye systems.
¶ Only period August 1998 - January 1999.
? Not measured.
Ni-N Inorganic N (NO_3^- -N + NH_4^+-N).

Table 2. Nitrogen balance for the different manure and crop treatments 1999-2000.

1999 – 2000	Ryegrass and clover				Maize / rye				Maize / maize	
(kg N ha^{-1} yr^{-1})	Control	SLDM	SHDM	FYM	Control	SLDM	SHDM	FYM	Control	SHDM
INPUTS										
Manure N	0.0	199.2	202.4	172.3	0.0	197.6	194.4	173.3	0.0	198.2
N Fixation §	197.1	165.7	197.1	197.1	0.0	0.0	0.0	0.0	0.0	0.0
Atmospheric N ¥	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0
TOTAL INPUTS	**222.1**	**389.9**	**424.5**	**394.4**	**25.0**	**222.6**	**219.4**	**198.3**	**25.0**	**223.2**
OUTPUT										
NH_3 volatilisation	0.0	69.2	74.6	19.1	0.0	0.0	0.0	0.0	0.0	0.0 #
Ni-N leaching	3.3	5.6	2.9	6.7	74.8	65.6	61.1	52.8	73.6	111.2
Denitrification	1.5	3.1	2.6	3.5	18.1	12.9	16.3	15.7	?	?
N uptake	209.7	277.4	280.3	268.0	179.1	252.8	258.7	212.0	144.4	217.4
TOTAL OUTPUTS	**214.5**	**355.3**	**360.4**	**297.3**	**272.0**	**331.3**	**336.0**	**280.5**	**218.1**	**328.6**
INPUTS-OUTPUTS	**7.6**	**34.6**	**64.1**	**97.2**	**-247.0**	**-108.7**	**-116.6**	**-82.2**	**-193.1**	**-105.4**
s.e.	**(14.80)**	**(19.13)**	**(6.71)**	**(14.61)**	**(22.74)**	**(25.31)**	**(6.75)**	**(5.50)**	**(15.15)**	**(15.68)**

§ Estimated from NFIXCYCLE model (Scholefield et al., 1996).
Y Estimated from values measured by Campbell et al. (1988) and Derwent et al. (1988).
 # Estimated from evaluations carried out on maize/rye systems.
? Not measured.
Ni-N Inorganic N (NO3- -N + NH4+-N).

Arable systems showed a reduction in soil N, which was only partially compensated for by manure applications but on the grass sward there was a positive N balance, suggesting accumulation of soil N. The results of this study suggest that agronomic management was more important than manure type in influencing N losses, where soil cultivation appeared to be a key factor when comparing N losses from arable and grass systems.

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