Efficiency and recovery of nutrients from different cattle manure applied on meadows

Godden B[1, 3*], Luxen P.[1, 2], and Knoden D.[2]

[1] Agra-Ost, Klosterstrasse 28, B 4780 St-Vith, Belgium
[2] Fourrages Mieux, rue du Carmel 1, B 6900 Marloie, Belgium
[3] ULB rue Engeland 642,1180 Bruxelles Belgium
* address: Centre Wallon de Recherches Agronomiques Département Production Végétale 4, rue du Bordia, B 5030 Gembloux Belgium
b.godden@cra.wallonie.be – bgodden@ulb.ac.be

Abstract

In mixed and dairy farms, animal manures are a major nutrient source for crops and grassland. Nevertheless mineral fertilizers are still intensively used due to the limited knowledge of the nutrient content of manures and effectiveness of supply.
In this field trial, different types of cattle manure (farmyard manure fresh or composted, semi solid manure and slurry) were compared with regard to their nutrient supply and agronomic efficiency.
Three rates of manure applications were considered (170, 210 and 250 kg N total/ha)
Applications of animal manures had provided an increase of DM yields from 18 to 30% as compared to the control 0 N (6.2 t DM/ha).
Efficiencies were around 40 kg dry matter/kg N applied and decreased with the N rate.
N apparent recoveries observed, were around 40 % for manure applications rates of 170 and 210 kg N/ha and dropped for application rates higher than 210 kg N tot/ha.
For cattle slurry the N apparent recoveries were respectively 50, 40 and 30 % for 170, 210 and 250 kg N/ha.
The N budget was always negative at the lower application rate, while the K budget was always negative for all the semi solid manure and the lower slurry application rates.

Introduction

In mixed and dairy farms, animal manures are a major nutrient source for crops and grassland as cattle excrete in urine and faeces more than 80 % of the nutrients contained in the diet (Whitehead 1995). Nevertheless mineral fertilizers are still intensively used (Kelm and Taube, 2005, Stilmant et al., 2000) due to the limited knowledge of the nutrient content of manures and effectiveness of supply. Another factor is that in mixed farms the major attention is given to arable crops, "cash crops" called. On the other hand, pastures are mainly located on less fertile parcels which are less accessible.
The Walloon legislation (PGDA – transposition of the Nitrate directive) which restricts more the application of organic N to crops (limit of 115 kg org N /year during the rotation) than to pastures (230 kg org N /ha including recycling of nutrients during grazing (PGDA, 2007)) will induce a temptation to spread higher amounts of manure to grassland.
In this field trial, different types of cattle manure (farmyard manure fresh or composted, semi solid manure and slurry) were compared with regards to their nutrient supply and their

I n the Proceedings of the "16th International CIEC Symposium16-19 Sept. 2007 Ghent"
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agronomic efficiency. Three rates of manure applications were considered (170, 210 and 250 kg total N /ha) according to the Walloon legislation.
As manures are also important sources of phosphorus and potash, the balance sheet of these elements is drawn up.

Materials and methods

These trials were conducted in Ellezelles (Hainaut, western part of Wallonia, Belgium; 75 m above sea level, characterized by a temperate climate: mean temperature 11.8 ° C, annual rainfall 730 mm) where grassland covers ± 35 % of the agricultural land surface.
They were carried during the 2002 to 2004 period on a permanent grassland dominated by perennial ryegrass, and with ± 15 % white clover.
The soil was a loamy soil showing these characteristics: 14.3 % clay, 70.4 % loam and 15.3 % sand, pH (KCl) 5.8, organic matter 4.7 %.

The experiment was conducted in a randomised block design with 4 replicates with a size plot of 12 m^2 (4 m x 3 m). Four different kinds of cattle manure were used in this study: slurry, semi-solid manure (SSM), farmyard manure (FYM) and composted farmyard manure (CFYM). A control treatment without any fertilizer was also included.
The annual application rates, according to the Walloon legislation at this time (PGDA, 2002) were :170 kg N/ha; 210 kg N/ha for all manures and also 250 kg N/ha for farmyard manure compost and slurry but for practical reasons not as fresh manure. The average composition of the applied manures is given in table 1.

Table1. Average composition of manures

Type of manure	Dry matter %	SD	Total N kg/t (1)	SD	$N\text{-}NH_4$ kg/t (1)	SD	C/N	SD	P_2O_5 kg/t (1)	SD	K_2O kg/t (1)	SD
Semi solid	17.30	2.46	4.75	0.94	1.48	0.21	13.34	4.71	2.45	0.42	3.9	0.34
Farmyard	20.85	2.01	3.51	0.91	0.90	0.35	21.53	4.99	1.83	0.31	4.85	1.04
Composted Farmyard	28.73	6.87	6.42	2.20	1.15	0.50	13.54	1.15	5.47	1.34	7.5	2.25
Slurry	8.05	1.33	3.35	0.59	2.52	0.43	8.31	0.64	1.49	0.18	2.9	0.29

(1) on fresh weight basis
SD: standard deviation

All manures were applied at the end of the winter (February – March) according to the legislation and the climatic conditions (no permanent frost …).

Nitrogen efficiencies and Nitrogen Apparent Recovery were calculated:
- N efficiency (Ne) = kg DM /kg N applied, and

- relative N efficiency (Ner) = (kg DM by grass cuts in a manure treatment - kg DM by grass cuts in the 0 N treatment)/ kg N applied
- Nitrogen Apparent Recovery (NAR) = N removed $_{org}$- N removed $_0$/ N tot $_{org}$
where
N removed $_{org}$ = annual nitrogen removed grass cuts in a manure treatment
N removed $_0$ = annual nitrogen removed grass cuts in a zero nitrogen treatment
N tot $_{org}$ = total nitrogen content of the manure applied

Results and discussion

Dry matter grass yields are given in table 2. Spreadings of animal manures had provided an increase of DM yields from 18 to 30% as compared to the control 0 N (6.2 t DM/ha).

Table 2 Annual grass production (cumulated dry matter for 3 cuts in t/ha)

Year Treatment	2002	2003	2004	Mean annual DM t/ha	In % Control 0 N	
Control 0 N	7.28	5.7	5.6	6.2		a
Composted FYM 170	8.1	5.8	8.01	7.3	118	b
Composted FYM 210	8.66	6.7	8.21	7.9	127	c
Composted FYM 250	8.76	6.4	8.7	8.0	128	c
Semi Solid M 170	8.8	5.9	8.36	7.7	124	bc
Semi Solid M 210	10.23	6.7	8.3	8.4	136	c
Farmyard M170	8.66	5.9	7.85	7.5	121	b
Farmyard M 210	9.37	6.9	7.89	8.1	130	c
Slurry 170	9.04	5.5	7.73	7.4	120	b
Slurry 210	8.92	6.2	7.66	7.6	123	b
Slurry 250	8.5	5.9	8.46	7.6	123	b

1 Values of the same column followed by the same letter are not significantly different according to Newman Keuls test ($P < 0.05$).

An increase in yield was observed with manure rates in FYM, SSM and CFYM but limited to 210 kg Nha^{-1}. For slurry no increase was observed. A single application of high rates of quick acting release N seems thus to be not efficient. One reason could be that a significant fraction ammonium from slurry is microbially shortly immobilized after application (Sörensen, 2004) due to relative high organic matter content (4.7 % OM is present in this loamy soil).
Only small differences of kg DM between organic fertilizers were observed.

Table 3 Efficiencies of N applied by manures

Treatment	kg N applied/ha	Ne (kg DM / kg N applied)	SD	Ner (kg DM / kg N applied)
Control 0 N	0	-	-	-
Composted FYM 170	170	42.94	7.66	6.53
Composted FYM 210	210	37.62	4.92	7.92
Composted FYM 250	250	32.00	5.41	7.04
Semi Solid M 170	170	45.29	9.21	8.78
Semi Solid M 210	210	40.00	8.41	10.56
Farmyard M170	170	44.12	8.38	7.51
Farmyard M 210	210	38.57	5.95	8.86
Slurry 170	170	43.53	10.50	7.24
Slurry 210	210	36.19	6.49	6.67
Slurry 250	250	30.40	5.94	5.71

SD: standard deviation

All N efficiencies were decreasing with application rates independently of the form of N applied but the relative efficiency was increased from 170 to 210 kg N/ha spreadings except for slurry (a quick release N source).

Efficiencies in this experiment are similar as those calculated from the data of Beckwith et al. (2002) for farmyard manure 40 kg DM/kg N applied, and lower for slurry (63 to 72 for slurry applied in February at 150kg N/ha and 32 to 37 for 300 kg N/ha).

Due to the presence of white clover at a similar level in all our plots, the relative efficiencies are much lower than for pure grass meadows (calculated from Beckwith et al., 2002).

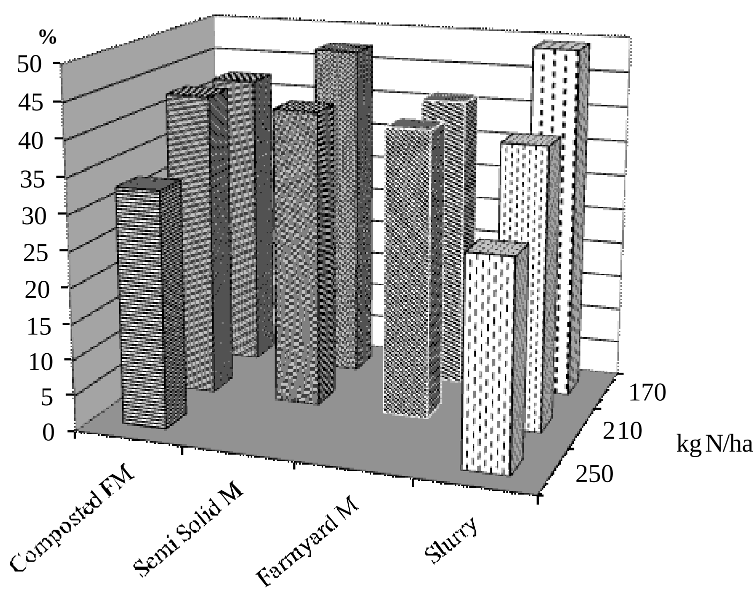

Figure 1. Apparent N recoveries

Apparent N recoveries (figure 1) calculated were around 40 % for manure applications rates of 170 and 210 kg N/ha and dropped for application rates higher than 210 kg total N /ha. For cattle slurry, the apparent N recoveries had decreased steadily from 50 to 30 % when the application rate was increased from 170 to 250 kg N/ha year.
These values are smaller than other cited in the literature for pure grass covers (Bittman et al., 2004). In this experiment there was an association of grasses and clover, the latter responsible For a significant contribution of N fixation.

Nutrient balance sheet

To evaluate the limiting N rate of manure on nutrients supply to meadows, nutrient budgets were calculated for N, P and K (table 4).

Table 4. Nutrient balance sheet (*)

	Supplies			Removed by grass			Nutrient balance sheet		
Treatment	N	P	K	N	P	K	N	P	K
Control 0 N	0	0	0	130	32	149	-130	-32	-149
Composted FYM 170	169	63	164	202	32	153	-34	31	11
Composted FYM 210	206	78	202	220	35	165	-14	43	37.4
Composted FYM 250	243	93	242	213	35	167	30	58	75.3
Semi Solid M 170	172	39	118	224	34	165	-53	5	-48
Semi Solid M 210	211	47	145	236	39	188	-25	9	-43
Farmyard M170	169	38	194	201	34	161	-32	5	33
Farmyard M 210	210	52	260	215	38	180	-6	14	80
Slurry 170	178	35	128	215	34	162	-37	1	-33
Slurry 210	218	43	158	213	35	164	4	7	-5
Slurry 250	258	51	187	203	33	149	56	18	38

(*) annual mean kg N, P or K /ha

N balance sheets were always negative at the application rate corresponding to 170 and 210 kg N/ha (except for slurry at 210, the N balance is 4 kg), while K budgets were always negative for all the semi solid manure and the two smallest slurry applications.
For semi solid manure a significant part of K is lost during storage (Dewes and Schmitt,1994).
For phosphorus, the balances are always slightly positive for this level of grass yield but except for composted manures (for which they are clearly positive).

Conclusions

As well in terms of grass yield, nitrogen efficiencies, and nutrients balances, manure applications rates higher than 210 seems to be not recommended.

Moreover it was observed for high rates of spreading un-composted manures a "degradation" of grass fodder quality (determined on basis of the botanical composition) has been observed (Knoden et al., 2007).
Nitrogen from manures is more efficient when rates and periods of spreading are adapted to grass growth potential; on late winter or early spring for quick acting N organic fertilisers as slurry.
Yields observed here can probably enhanced to a more profitable performance for farmers, by a sound mineral N fertilizer but in the case of slow acting manures (FYM, CFYM, SSM) it can probably be more interesting to apply this at a moderate rate in early spring.

Acknowledgements

This research was partially supported by the Ministry of the Walloon region (MRW-DGA)

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