The effect of contrasting cattle and pig farmyard manure (FYM) management practices on crop nitrogen utilisation

J.R. Williams[*1], E. Sagoo[1], B.J. Chambers[2] and D.R. Chadwick[3]*
[1] ADAS Boxworth, Battlegate Road, Boxworth, Cambridge CB23 4NN, UK
[2] ADAS Gleadthorpe, Meden Vale, Mansfield, Notts., NG20 9PF, UK.
[3] IGER, North Wyke, Okehampton, Devon EX20 2SB
e-mail: john.williams@adas.co.uk

Introduction

In the UK, *c.*46 million tonnes of solid manure are applied to agricultural land each year, containing an estimated 330,000 tonnes of total nitrogen - N (Williams *et al.,* 2000). In straw-based farmyard manure (FYM), typically 10-25% of the total N content is present as readily available N (i.e. ammonium-N), with the remainder present in organic forms that will slowly become available following mineralisation over a period of months to years. The ammonium-N content of solid manure is at risk of loss following land spreading, principally via ammonia volatilisation and nitrate leaching losses. Efficient utilisation of manure N is essential if ammonia volatilisation and nitrate leaching losses from agriculture are to be reduced, and the economic value of manure applications maximised.

Measures to conserve ammonia during FYM storage (e.g. heap covering) are likely to increase the total N content of the manure at land spreading, compared with conventional 'open-air' storage methods, which may in turn increase the potential to emit ammonia and cause nitrate leaching losses following land spreading, as well as improving crop N utilisation. Also, rapid soil incorporation to reduce ammonia emissions following land spreading may lead to increased nitrate leaching losses where applications are made in the autumn/winter period.

Materials and methods

The effects of contrasting FYM storage methods, soil incorporation techniques (plough or disc) and the time delay between application and soil incorporation (4 or 24 hours) on the fertiliser N replacement value of straw-based pig and cattle FYMs was studied at ADAS Gleadthorpe (Notts.) and IGER North Wyke (Devon). 'Fresh' FYM was applied in April 2000 and stored FYM in September/October 2000 at both sites. The storage treatments included: conventional 'open-air' heaps; rate of straw bedding addition (two rates for cattle FYM and one rate for pig FYM); heap covering with a plastic sheet and turning the heaps twice (pig FYM only). All manures were applied to cereal stubbles at a target rate of 250 kg total N/ha, before grass was established on all the plots, with each treatment replicated 3 times in a randomised block design.

Ammonia emissions were measured from all the FYM treatments following land spreading using the dynamic chamber technique, and nitrate leaching losses were measured from selected autumn applied FYM treatments (and an untreated control), using porous ceramic cups. Additional plots received inorganic fertiliser N applications at six incremental rates (0-200 kg/ha N) to quantify the fertiliser N replacement value of the different FYM treatments. Grass fresh weight and dry matter yields, and N offtakes were measured at harvest from all treatments. The fertiliser N replacement value of the contrasting 'fresh' and stored FYM and cultivation treatments was estimated, using grass dry matter yield data (Schroder, 2005).

Results and discussion

(i) Ammonia emissions and grass N recovery following land spreading of 'fresh' FYM

Ploughing 'fresh' pig FYM into the soil after 4 and 24 hours and disking after 4 hours of land spreading reduced ammonia losses (P<0.05) compared with surface broadcast application (41% of total N applied) by 84%, 64% and 60%, respectively. However, disking after 24 hours did not reduce (P>0.05) ammonia losses compared with surface spreading. Ploughing 'fresh' cattle FYM into the soil 4 hours after land spreading reduced losses by *c.*80 % compared with leaving the FYM on the soil surface. Disking after 4 or 24 hours or ploughing after 24 hours of land spreading reduced ammonia losses by 45-60% compared with leaving the FYM on the soil surface.

The reductions in ammonia loss as a result of rapid soil incorporation improved manure N use efficiencies compared with leaving the FYM on the soil surface. Grass N offtakes were greatest (P<0.05) at 26% of total N applied where the 'fresh' pig FYM was ploughed into the soil after 4 hours of land spreading (Table 1). N offtakes on the surface spread, ploughed after 24 hours, disced after 4 hours and disced after 24 hours treatments were not different (P>0.05) from each other at between 9 and 18% of total N applied. The N efficiency of the pig FYM (i.e. the fertiliser N replacement value expressed as a percentage of total manure N applied) ranged between 8 and 13% of total N applied for the surface spread and disced after 4 and 24 hour treatments. Ploughing after 24 hours increased N efficiency of the 'fresh' FYM by over 2-fold compared with the other treatments to 28% of total N applied.

Table 1. Grass N offtakes, fertiliser N replacement values and manure N efficiencies for spring applied 'fresh' pig and cattle FYM treatments

Manure type and soil incorporation treatment (application timing)	Grass N offtake (% manure total N applied) value#	Fertiliser N replacement (kg/ha)	Manure N efficiency (%)
Pig FYM (April 2000)			
Surface spread	9.3^{ab} (4.6)	21	8
Disked after 4 hours	12.8^{ab} (2.1)	36	13
Disked after 24 hours	10.7^{ab} (3.0)	29	11
Ploughed after 4 hours	25.9^{c} (1.3)	> max	-
Ploughed after 24 hours	18.0^{bc} (4.0)	76	28
Cattle FYM (April 2000)			
Surface spread	1^{a} (0.7)	0	0
Disked after 4 hours	6^{ab} (1.9)	14	9
Disked after 24 hours	0^{a} (4.9)	0	0
Ploughed after 4 hours	16^{b} (2.3)	52	33
Ploughed after 24 hours	18^{b} (3.8)	58	36

Based on grass dry matter yield. >max = yield exceeded maximum on inorganic fertiliser N plots
Letters indicate differences between treatments (P<0.05)

Grass N offtakes were highest (P<0.05) where the cattle FYM was ploughed into the soil after 4 and 24 hours of land spreading at 16 and 18% of total N applied, respectively. Grass N offtakes on the surface spread, disked after 4 and after 24 hours treatments (where ammonia losses were higher than on the ploughed treatments) ranged between 0 and 6% of total N applied. Manure N efficiencies of the ploughed after 4 and 24 hours treatments were 33 and 36% of total N applied, respectively, compared with between 0 and 9% of total N applied for the surface spread and disked treatments.

(ii) Ammonia emissions, nitrate leaching losses and grass N recovery from contrasting FYM storage treatments

Following the land spreading of stored pig FYM in September 2000, manure N offtakes were highest (P<0.05) at 12% of total N applied, where the conventionally stored FYM had been ploughed into the soil 4 hours after spreading compared with leaving the FYM on the soil surface (N offtake 5% of total N applied). Grass N offtakes following application of the sheeted (surface applied and ploughed into the soil), extra straw and turned FYM storage treatments ranged between 5 and 7% of total N applied and were not different from each other (P>0.05). Fertiliser N replacement values were highest following application of the sheeted FYM that was ploughed into the soil 4 hours after land spreading at 52 kg/ha N (manure N efficiency 25%) and where the sheeted FYM was left on the soil surface at 39 kg/ha N (manure N efficiency of 18%). Fertiliser N replacement values from the surface spread extra-straw, conventional and turned pig FYM treatments were lower at 28, 21 and 13 kg/ha N (manure N efficiencies 11, 12 and 5% of total N applied), respectively.

Table 2. Grass N offtakes, fertiliser N replacement values and manure N efficiencies of autumn applied stored pig and cattle FYM treatments

Manure type and soil incorporation treatment (application timing)	Grass N offtake (% manure total N applied)	Fertiliser N replacement value#	Manure N efficiency (%) (kg/ha)
Pig FYM (September 2000):			
Conventional – surface spread	4.6[a] (1.4)	21	12
Conventional – ploughed after 4 hours	11.8[b] (1.6)	>max	-
Straw + 50% - surface spread	5.9[a] (1.5)	28	11
Sheeted – surface spread	3.9[a] (2.5)	38	18
Sheeted – ploughed after 4 hours	7.1[a] (2.0)	52	25
Turned – surface spread	4.7[a] (2.5)	13	5
Cattle FYM (October 2000):			
Conventional – surface spread	5 (1.8)	1	1
Conventional – ploughed after 4 hours	0 (1.9)	0	0
Sheeted – surface spread	6 (1.5)	14	7
Sheeted – ploughed after 4 hours	4 (4.9)	6	3
Straw+ 50% – surface spread	9 (5.3)	20	12
Straw + 100% – surface spread	2 (3.8)	4	2

Based on grass dry matter yield. >max= yield exceeded maximum on inorganic fertiliser N plots
Letters indicate differences between treatments (P<0.05)

For cattle FYM, none of the contrasting storage or soil incorporation treatments had any effect (P>0.05) on grass N offtakes (Table 2). Grass N offtakes ranged between 0 and 9% of total N applied, fertiliser N replacement values between 0 and 20 kg/ha N and N efficiencies between 0 and 12% of total manure N applied. The low grass yield responses and manure N efficiencies reflected the low ammonium N content of the stored cattle FYM (< 6% of total N applied) and contrasted with the greater grass yield responses and higher ammonium-N contents of the stored pig FYMs (range 11-55% of total N applied).

Nitrate leaching losses were increased where pig FYM had been ploughed into the soil 4 hours after land spreading (to reduce ammonia emissions) compared to leaving the FYM on the soil surface; for the conventionally stored pig FYM nitrate leaching increased from 16 to 22% of total N applied and for the sheeted stored pig FYM from 13 to 21% of total N applied. For cattle FYM, nitrate leaching losses were equivalent to less than 1% of total N applied and reflected the low ammonium-N content of the applied cattle FYMs.

Conclusions

Ploughing spring applied 'fresh' pig FYM into the soil after 4 hours and 'fresh' cattle FYM after 4 and 24 hours increased (P<0.05) grass N offtakes compared with leaving the FYM on the soil surface. The increased grass N offtakes (and manure N efficiencies) reflected reductions in ammonia volatilisation losses to air compared with leaving the FYM on the soil surface. For pig FYM, N use efficiencies ranged between 8 and 28% of total N applied (28% where the FYM was ploughed into the soil after 24 hours and in the range 8-13% of total N applied when the FYM was left on the soil surface or disked into the soil after 4 and 24 hours). For cattle FYM, N use efficiencies ranged between 0 and 36% of total N applied (33 and 36% where the FYM was ploughed into the soil after 4 and 24 hours, respectively compared with 0 to 9% following surface spreading or disking after 4 and 24 hours).

Sheeting the pig FYM during storage (to reduce ammonia losses) and ploughing into the soil 4 hours after land spreading resulted in a higher manure N use efficiency (25% of total N applied) compared with conventional 'open-air' storage and leaving the FYM on the soil surface (12% of total N applied). However, elevated nitrate leaching losses (*c.*50% increase) were also measured where the pig FYM was autumn applied and ploughed into the soil 4 hours after land spreading compared with leaving the FYM on the soil surface.

For cattle FYM, none of the contrasting storage and soil incorporation treatments had any effect on manure N efficiencies or nitrate leaching losses, reflecting the low ammonium-N content of the FYMs at the end of storage (<6% of total N applied).

Acknowledgement

Funding of this work by the Department for Environment, Food and Rural Affairs (Defra) is gratefully acknowledged.

References

Schroder, J.J. (2005). Manure as a Suitable Component of Precise Nitrogen Nutrition. The International Fertiliser Society, York, Proceedings 574. ISBN 0853102112.

Williams, J.R., Chambers, B.J., Smith, K.A. and Ellis, S. (2000). Farm manure land application strategies to conserve nitrogen within farming systems. In: Agriculture and Waste Management for a Sustainable Future (Eds. Petchey T., D'Arcy, B. and Frost, A.), The Scottish Agricultural College, pp 167-179.