Field studies of farm manure organic nitrogen mineralisation

Etude au champ de la minéralisation de l'azote organique des déjections animales.

J.R. Williams
ADAS Boxworth, Battlegate Road,
Boxworth, Cambridge, CB3 8NN. UK.
E-mail : John_Williams@adas.co.uk

B.J. Chambers, A. Bhogal
ADAS Gleadthorpe, Meden Vale,
Mansfield, Notts. NG20 9PF. UK.

D. Chadwick, B.F. Pain
IGER North Wyke, Okehampton
Devon, EX20 2SB. UK.

Abstract

Field experiments and pot incubation studies were used to quantify nitrogen (N) mineralisation from the organic fraction of farm manures. A methodology was developed to 'strip' manures of their readily available N contents to reduce the masking effects of readily available N on mineralisation measurements. In the pot incubation study the greatest N mineralisation was from a layer manure (55% of total organic N applied) and a pig slurry (37%), and least from a dairy slurry (2%) and beef FYM (6%). The amount of organic N mineralised was inversely related to the carbon:organic N ratio of the manures (P<0.01). Results from the 3 field experiments on contrasting soil types were in general agreement with the pot incubation studies with the largest amount of mineralisation occurring on the layer manure and pig slurry treatments and least following cattle slurry and FYM additions. Models that predicted between 10 and 20% of manure organic N would mineralise in the season following application provided the best agreement with field measurements, although none of the models successfully predicted mineralisation differences between manure types.

Key words: Farm manures, organic nitrogen, mineralisation, modelling

Résumé

Des essais au champ ainsi que des incubations en pots ont été utilisés pour quantifier la minéralisation de la fraction azote organique des déjections animales. Une méthode a été développée pour « appauvrir » les déjections de leur fraction azote minéral disponible afin d'éviter les interférences sur les mesures de minéralisation. Dans les essais d'incubation en pots, le taux maximum de minéralisation est obtenu à partir du fumier de volailles (55% de l'N organique total apporté) et du lisier de porc (37%), alors que des taux plus faibles furent obtenus avec le lisier bovin (2%) et le fumier bovin (6%). La quantité d'azote organique minéralisé est inversement corrélée au ratio carbone sur azote organique des déjections (P < 0.01).

Les résultats issus de 3 essais au champ sur des sols différents confirment les observations en laboratoire. Les modèles qui prédisent qu'un taux de minéralisation compris entre 10 et 20% sera obtenu au cours de la saison suivant l'épandage corroborent les résultats obtenus au champ, mais ne permettent toutefois pas d'expliquer les différences entre les différents types de déjections.

Mots-clés : Déjections animales, azote organique, minéralisation, modélisation.

1. Introduction

In the UK, applications of animal manure to agricultural land supply ca. 450,000 tonnes of nitrogen per annum, of which ca. 300,000 tonnes are estimated to be present as organic N and ca. 150,000 tonnes in readily plant available N forms (principally ammonium and uric acid-N). Typically, 75-90% of the total N content of straw-based farmyard manures (FYM) is present as organic N, 50-60% for poultry manures and 40-50% for slurries (MAFF, 1994).

Research in the UK has largely focused on readily available N forms as these have the greatest influence in the short-term on crop fertiliser N supply, ammonia volatilisation and nitrate leaching losses (Jarvis and Pain, 1990; Unwin et al., 1991; Chambers et al., 1997). In the longer-term, organic N mineralisation will have increasingly important effects on N supply, particularly in situations where repeated manure applications are made to land. If mineralisation of the applied organic N occurs during periods of crop growth (spring-summer) fertiliser N requirements will be reduced, but if mineralisation occurs during the autumn-winter period, nitrate leaching and denitrification losses are likely to increase.

This paper describes results from pot incubation and field studies to quantify N mineralisation from the organic fraction of farm manures. Mineralisation measurements at the field sites were compared with values predicted by selected manure N models.

2. Methodology

Quantifying organic N mineralisation is complicated by the presence of often large quantities of readily available N (principally ammonium-N and for poultry manures, uric acid -N). Methodologies involving sedimentation (for slurries) and controlled drying were developed to "strip" the manures of their readily available N contents. The techniques were effective for the pot incubation studies (17 manure samples) and field experiments (9 manure samples) at reducing the readily available N content of the cattle manure samples to < 1% and < 5% of total N, for the pig manure samples < 2% and < 10%, and for the poultry manure samples < 3% and < 10%, respectively.

2.1. Pot incubation studies.

N mineralisation from the organic N fraction of 17 manures (3 cattle slurry, 3 cattle FYM, 3 pig slurry, 4 pig FYM and 4 poultry manures) was measured under uniform conditions of light (16 hour photo period), temperature (18°C days and 12°C nights) and soil moisture status (60% of moisture holding capacity) for a period of 6 months. The ammonium -N "stripped" manures were mixed with a loamy sand textured soil in pots 16.5 cm x 16.5 cm x 20 cm), and sown with perennial ryegrass (*Lolium perenne* L.). The treatments were arranged in a randomised block design with three replicates of each treatment.

The manures were analysed for dry matter, organic carbon (C), total N, ammonium-N and for poultry manures, uric acid-N. Target applications were 200 kg/ha total N with additional phosphorus, potassium and sulphur applied in solution to the pots to ensure that grass growth was not limited by an inadequate supply of major nutrients other than nitrogen. Six grass cuts were taken during the experiment, with the ryegrass N offtakes used as a measure of organic N mineralisation.

2.2. Field studies

In June 1996, field experiments were established at 3 sites with contrasting soil types and climatic conditions (Table 1), to measure N mineralisation from the organic N fraction of 9 farm manures (2 cattle slurry cattle FYM and pig FYM, 1 pig slurry, layer manure and broiler litter) and six inorganic N treatments (0-150 kg/ha). There were 3 replicates of each treatment in a randomised block design.

At each site, ammonium-N "stripped" manures were applied to the plots (3 m x 10 m) prior to the establishment of perennial rye grass. The manures were left on the soil surface for 48 hours after application to encourage further ammonia volatilisation before incorporation. 1 m^2 mesh squares were placed randomly on each plot before application so that samples of the manures could be collected at the time of soil incorporation. The manure samples were analysed for dry matter, total C, total N, ammonium-N and for poultry manures uric acid-N, so that the amount of N applied to each treatment could be quantified (Table 2). At ADAS Rosemaund, extremely dry weather after the experiment was set up meant that the grass did not germinate. Grass was satisfactorily established on the plots in February 1997.

Site	Soil texture	Average annual rainfall (mm)	Topsoil total N (%)	Topsoil organic matter (%)
ADAS Gleadthorpe	Loamy sand	650	0.04	1.7
ADAS Rosemaund	Silty clay loam	800	0.20	2.9
IGER North Wyke	Sandy loam	1000	0.08	1.8

Table 1.
Soil type, cropping and average annual rainfall

Between June 1996 and June 1997, 5 grass cuts were taken at Gleadthorpe and 4 at North Wyke. The late grass establishment at Rosemaund meant that only 1 cut was possible.

	Total N loading (kg/ha)		
Treatment	Gleadthorpe	North Wyke	Rosemaund
Cattle FYM 1	526	632	1366
Cattle FYM 2	901	848	824
Pig FYM 1	863	1031	816
Pig FYM 2	794	861	1024
Cattle slurry 1	172	364	231
Cattle slurry 2	676	724	569
Pig slurry	577	543	639
Layer manure	674	364	326
Broiler litter	659	638	444

Table 2.
N loadings at each field site following application of ammonium-N stripped manures

Porous ceramic cups (Webster et al., 1993) were installed at 90 cm depth on each manure treatment (4 per plot) to measure nitrate leaching losses. Drainage estimates were made using the IRRIGUIDE meteorological model (Bailey and Spackmann, 1996) with leachate samples collected every 2 weeks or following 25 mm of drainage whichever occurred sooner, for nitrate-N analysis. Nitrate-N concentrations in porous cup samples were combined with drainage volume estimates between the sampling dates to measure nitrate-N leaching losses (Lord and Shepherd, 1993). Soil temperatures were measured daily and soil moisture contents monthly.

The sum of plant N uptakes and nitrate leaching measurements on the control was subtracted from those on the manure treated plots to quantify organic N mineralisation. The mineralisation measurements were corrected for the small amount of readily available N applied in the manures.

Dry matter yields on the manure treatments in year 1 were compared with the yields on the inorganic N treatments to calculate the fertiliser equivalent value of the mineralised organic N.

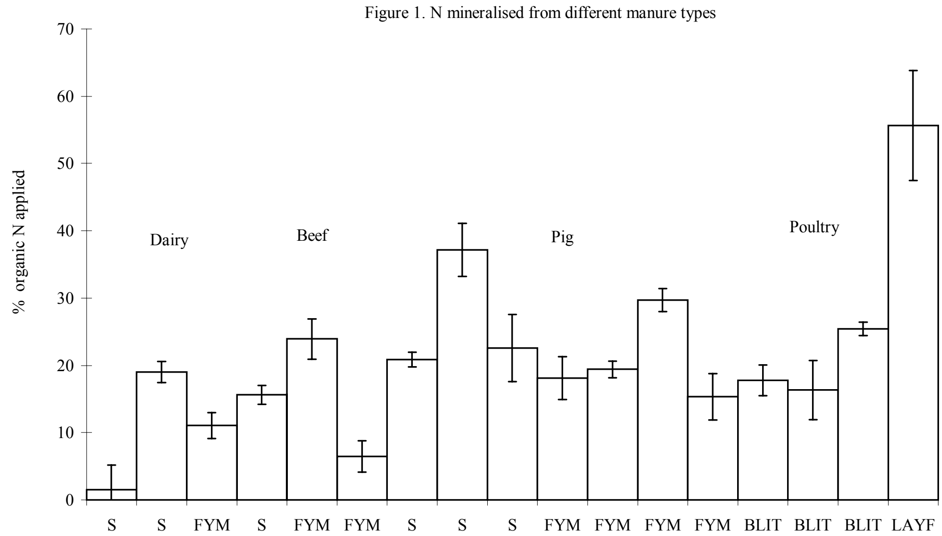
2.3. Modelling

Field assessments of manure organic N mineralisation at Gleadthorpe and North Wyke were compared with predictions from N-CYCLE (Scholefield et al., 1991), MANNER (Chambers et al., 1998) and other manure models; Beauchamp and Paul (1989), Bhat et al., (1989) and Diltz et al., (1990).

3. Results and discussion

3.1. Pot Incubation studies

Net N offtakes were greatest from a layer manure (115 kg/ha N) and a pig slurry (60 kg/ha N) and least from a dairy slurry (3 kg/ha N) and a beef FYM (13 kg/ha). During the 60 days following incorporation of the manures, net immobilisation was measured on the dairy slurry and beef FYM treatments. By the fourth harvest (120 days), the mineralisation rates had decreased to low, relatively constant levels for all manure types.



Notes S = slurry, FYM = farmyard manure, BLIT = broiler litter, LAY = layer manure

Figure 1
Mineralised from different manure types.

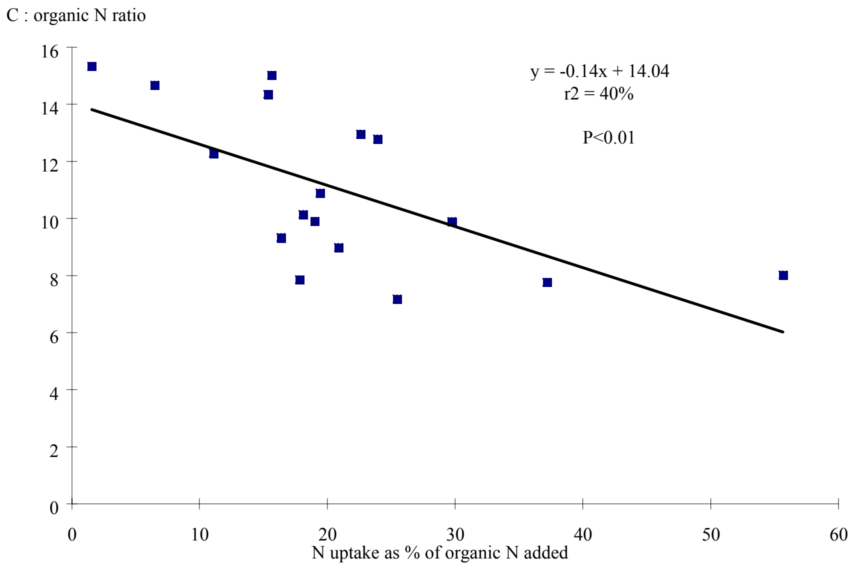


Figure 2
Relationship between %N mineralisation and C : organic N ratio.

The % organic N mineralised (Figure 1) was greatest from a layer manure (55%) and a pig slurry(37%) and least from a dairy slurry (2%) and a beef FYM (6%). The amount of organic N mineralised was inversely proportional to the C:organic N ratio of the manures ($P < 0.01$, $r^2 = 40\%$,), - Figure 2.

3.2. Field studies

N uptake
At Gleadthorpe, uptakes of mineralised organic N were greatest on the pig slurry and layer manure treatments with 265 and 200 kg/ha N taken up respectively between June 1996 and June 1997, respectively. On the cattle FYM-2 and pig FYM-2 treatments, there was no net N mineralisation between the first and fourth sampling dates (8 months). Net N uptakes on these treatments were 30 and 23 kg/ha N, respectively.

At North Wyke grass N uptakes were generally greater than at Gleadthorpe for all the manure treatments which may reflect warmer soil temperatures in the autumn following application (Figure 3). Between June 1996 and June 1997, the greatest N uptakes were measured on the layer manure and pig FYM-1 treatments at ca. 339 and 323 kg/ha N, respectively. The lowest N uptakes at 36 kg/ha N was measured on the cattle slurry -1 treatment. N uptake on the other treatments ranged between 145 and 280 kg/ha N.

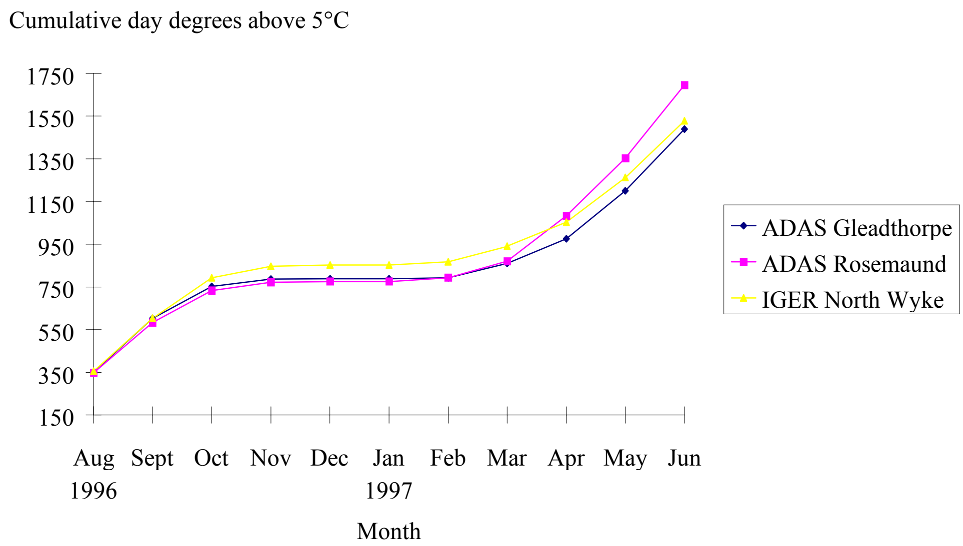


Figure 3
Cumulative day degrees above 5°C at 10 cm soil depth.

At Rosemaund, N uptakes were lower than the other sites because of the late grass establishment. The greatest uptake was 140 kg/ha N measured on the pig slurry treatment and least 27 kg/ha on the cattle slurry - 2 treatment.

At all three sites net N mineralisation was continuing 18 months after the manures had been applied.

Nitrate leaching
At Gleadthorpe and North Wyke, nitrate leaching losses from the cattle FYM, cattle slurry and pig FYM-2 treatments were similar at ca. 5 kg/ha N. Losses on the pig FYM-1, pig slurry and poultry manure treatments were ca. 10, 15 and 20 kg/ha N at Gleadthorpe, and 25, 50 and 10 kg/ha N at North Wyke, respectively. The failure to establish a grass cover at Rosemaund meant that there was no plant N uptake before drainage began over winter 1996/97 and as a consequence nitrate leaching losses were overall greater than at the other sites in the range 25-50 kg/ha N.

Mineralisation
Generally, organic N mineralisation (sum of net plant uptake and net N leached) was greatest following the pig slurry and layer manure applications, with 52% and 36% of the applied organic N mineralised at Gleadthorpe, and 67% and 60% at North Wyke, respectively. At Rosemaund the greatest amount of mineralisation occurred on the cattle slurry-2 treatment (31%) followed by the pig slurry treatment (25%), Figure 4.

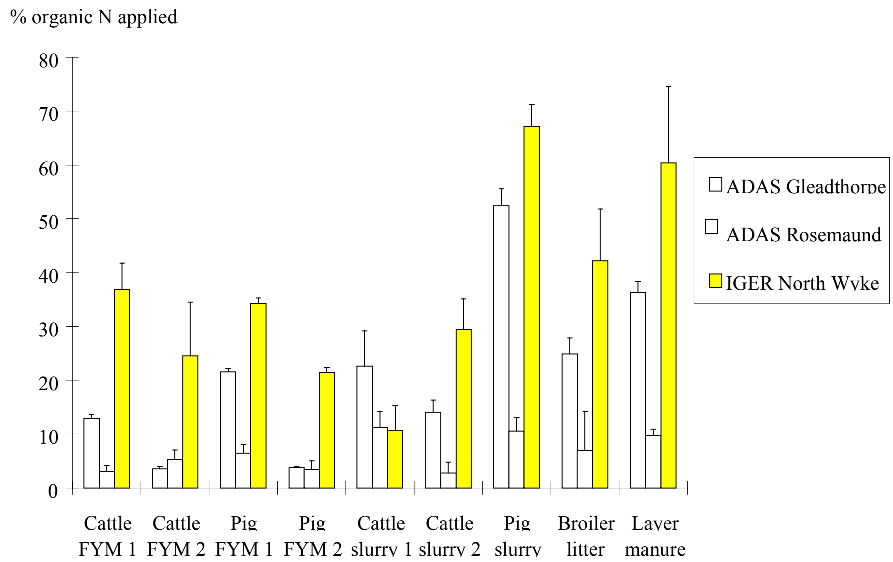


Figure 4
Net mineralisation between June 1996 to June 1997.

The field mineralisation measurements were in general agreement with those obtained in the pot incubation study, although it was not possible to establish a relationship between the field N mineralisation measurements and C : organic N ratio of the applied manures.

In the first growing season following application (i.e. six months from June to December), grass dry matter yields on the cattle FYM - 1, cattle FYM -2 and cattle slurry - 2 treatments were equivalent to those from inorganic fertiliser N applications of 96, 101 and 117 kg/ha N at Gleadthorpe and 88, 102 and 84 kg/ha N at North Wyke, respectively. Dry matter yields on the pig FYM-2 treatment at Gleadthorpe, the pig FYM -1 and broiler litter treatments at North Wyke were equivalent to 121, 129 and 89 kg/ha fertiliser N applications, respectively. It was not possible to calculate fertiliser N equivalents for the other treatments because dry matter yields exceed those of the 150 kg/ha fertiliser N applications. At Rosemaund failure to establish a grass crop meant that it was not possible to determine fertiliser N equivalents in the first season following manure application.

Modelling
The field measurements of N mineralisation at Gleadthorpe and IGER (June 1996 to June 1997) were compared with model predictions. Comparisons of the field measurements and model predictions for cattle FYM-1, layer manure and pig slurry treatments are shown in Figure 5 and Figure 6.

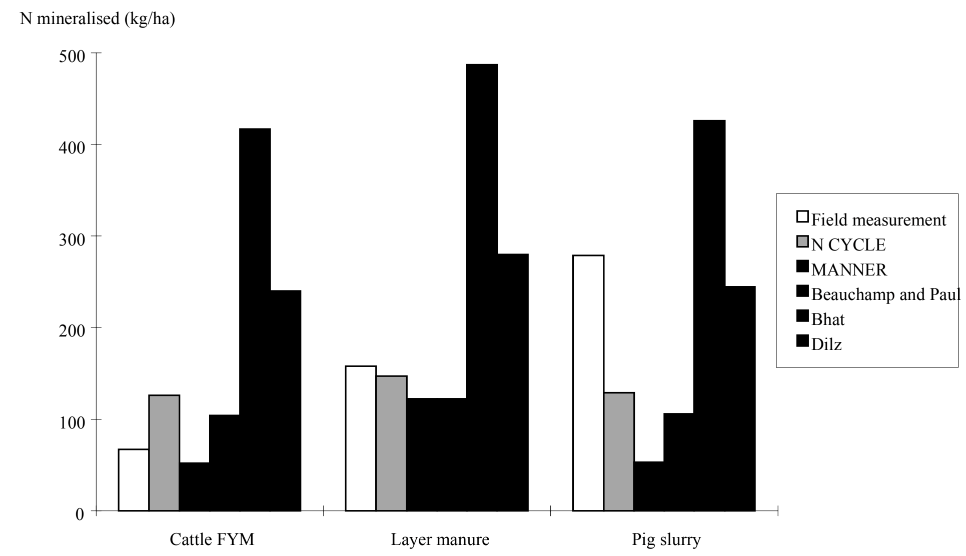


Figure 5
Predicted and measured N mineralisation, ADAS Gleadthorpe

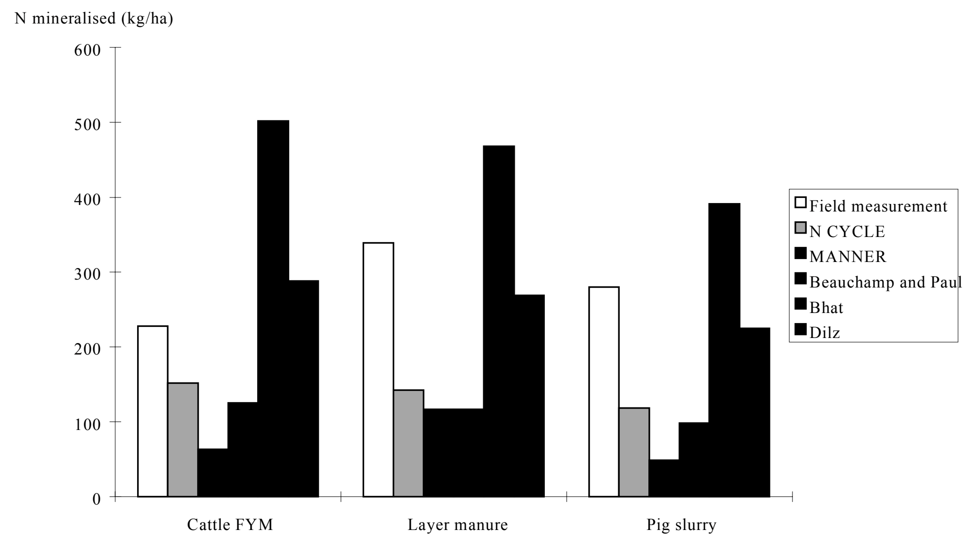


Figure 6
Predicted and measured N mineralisation, IGER North Wyke.

In general, the best quantitative predictions were provided by N-CYCLE, MANNER and the Beauchamp and Paul (1989) model. This was because these models estimated that between 10 and 20% of the organic N was mineralised in a first growing season after application. The Bhat et al. (1989) and Dilz et al. (1990) models over estimated mineralisation under these conditions, because they assumed that 80% and 46% respectively of the organic N would mineralise. None of the models were able to predict mineralisation differences between the manure types.

5. Acknowledgement

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