Course of nitrogen mineralisation after application of organic fertilisers at different times of the year

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Abstract

To achieve high nitrogen (N) use efficiency, the availability of N from organic fertilisers must be synchronised with crop uptake. In order to estimate when previously unmineralised N is plant-available in relation to fertilisation time-point, net N mineralisation was studied in incubations under natural temperature conditions at different times of the year. Organic fertilisers were mixed with soil and incubated in plastic bottles placed in topsoil on different dates throughout the year, simulating fertilisation in autumn, early spring, spring (at sowing) and early summer. The fertilisers studied were meat and bone meal (Biofer), dairy slurry, dairy farmyard manure, chicken manure and a by-product from yeast production (Vinasse). The soil used was a sandy loam in south-west Sweden. Bottles were taken up for analysis of NH_4-N and NO_3-N on 3-7 occasions until late autumn after the end of the growing season. Dairy slurry and dairy manure had negligible N mineralisation after application. About 55-60% of N in Biofer mineralised within 40-50 days. The N mineralisation rate of Vinasse was similar or slower and reached about 65% within 60-100 days. Chicken manure had a large initial mineral N content (50%) and had about 65% of total N in mineral form within 30-40 days. Incubation in the laboratory (15°C) showed a lower N mineralisation potential and less variation between fertilisers. However, mineralisation rate in terms of growing degree days (GDD) to mineralise a certain percentage of organic N was comparable between field and laboratory incubations.

Introduction

Within organic farming in particular, increasing amounts of waste products from the food industry are being used in addition to manure to cover crop nitrogen (N) needs. These different organic fertilisers release N at different and often unknown rates. To achieve high N use efficiency with maximised yield returns and minimised N losses to the environment, the availability of N from organic fertilisers must be synchronised with crop uptake. By documenting the course of mineralisation under field conditions, it should be possible to estimate when as yet unmineralised nitrogen becomes plant-available in relation to the time of fertilisation. This is needed to determine when to fertilise to get maximum N effect. In various studies, the course of mineralisation for a number of organic fertilisers has been studied under controlled laboratory conditions *(Griffin and Honeycutt, 2000; Raupp, 2005; Cordovil, 2007)*. In past research, thermal units or growing degree days (GDD) have been used successfully to predict cumulative N mineralisation through a growing season for organic material *(Honeycutt et al., 1988).* However, since net N mineralisation is the result of many processes (mineralisation and immobilisation) differently affected by temperature, the translation of laboratory values with constant temperatures in the range 15-25°C may prove difficult for mineralisation at temperatures fluctuating between -5°C and +20°C.

In this project the aim was to study the course of N mineralisation under natural temperature conditions in order to estimate when the unmineralised nitrogen in some organic fertilisers became plant available in relation to different times of fertilisation. The results obtained were compared with those of a parallel study involving incubations in a climate chamber (*Orvendal, 2007*) to determine whether the mineralisation predictions could have been based on laboratory incubations in terms of GDD.

Materials and methods

Five different organic fertilisers (Table 1) were mixed with soil and incubated in plastic bottles to keep ammonium N (NH_4-N) and nitrate N (NO_3-N) within the studied system, thus allowing any changes in mineral N over time to be studied. The fertilisers were meat and bone meal (Biofer 7-9-0), dairy slurry, dairy farmyard manure, chicken manure and a by-product from yeast production (Vinasse). Between 1 and 20 g of fertiliser, depending on N concentration, were mixed with soil to a total of 400 g, to correspond to a fertilisation rate of 100 kg tot-N ha^{-1}.

Table 1. Dry matter content and total-N and ammonium N content of the five types of fertiliser included in the study

	Chicken manure	Dairy manure	Vinasse	Biofer	Dairy slurry
DM %	35	15	64	92	8.7
TotN, kg ton-1	20	4.3	35	67	2.9
NH_4-N, kg ton-1	9.1	0.7	2	0	1.3

To study changes in mineral N under natural temperature conditions, the bottles were placed in the topsoil of a field in south-west Sweden at different times of the year, simulating times of fertilisation. The bottles were aerated through a pipe protruding from the soil surface. The soil temperature was measured continuously over time. On all occasions when bottles were placed in the field, a treatment with only soil was added to determine the soil organic material contribution to mineralisation. The soil used for incubation was a sandy loam with a soil moisture content of 50% of water holding capacity (WHC), which was considered moist enough to allow mineralisation and dry enough to allow aeration. Each treatment had three replicates, which were placed in the field at 2-4 different simulated fertilisation times (autumn, early spring, spring (at sowing) and early summer) depending on the type of fertiliser. Bottles were taken up for analysis of NH_4-N and NO_3-N (*Mulvaney*, *1996*) on 3-7 occasions depending on time of fertilisation and the results obtained were used to describe the course of mineralisation from the time of fertilisation until late autumn after the end of the growing season. The field incubations were then compared with incubations in a climate chamber (15°C) for 56 days (*Orvendal, 2007*), where fertiliser and soil were mixed in the same manner as for field incubations and placed in plastic cups in three replicates. Each replicate was placed on a tray covered with a plastic bag to prevent drying out. The bags were opened weekly during the first four weeks to allow aeration. Cups were taken out for analysis of NH_4-N and NO_3-N (*Mulvaney*, *1996*) after 3, 7, 14, 28 and 56 days. Attempts were made to predict net N mineralisation in terms of GDD (growing degree days, defined as sum of daily mean temperature above 0°C) to allow laboratory values to be converted to field conditions and to compare the rate of mineralisation between times of fertilisation. Mineral N was plotted against both days and GDD. Exponential equations were fitted to the data to describe cumulative organic N mineralisation in addition to initial mineral N, according to [$minN = minN_0 + N_0(1-exp(-kt))$], where *minN* is mineral N from applied manure after *t* days or GDD, $minN_0$ is mineral N from the start, N_0 is mineralisable N and *k* the mineralisation constant.

Results and discussion

Temperature varied between -4 and +20°C during the investigation period (Figure 1).

The net N mineralisation rates were similar between times of applications in most cases (Figure 2), and differences in mineralisation rate between times of application could only be related to temperature for Biofer. The mineralisation data were therefore plotted on the same graph for all times of application and against both days and GDD (Figure 3). Exponential equations were successfully fitted to the plotted data for Biofer, Vinasse and chicken manure and for dairy slurry when one time of application (spring 2005) with large immobilisation (Figure 2) was excluded (Figure 3). Dairy manure had net N immobilisation in 2005 and net N mineralisation in 2006 (Figure 2). Due to these inconsistencies and since the amounts of mineral N from dairy manure were negligible, no equation is presented for those data.

Figure 1. Soil temperature during the investigation period

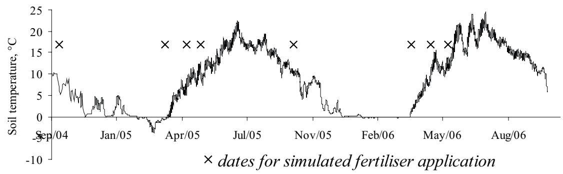
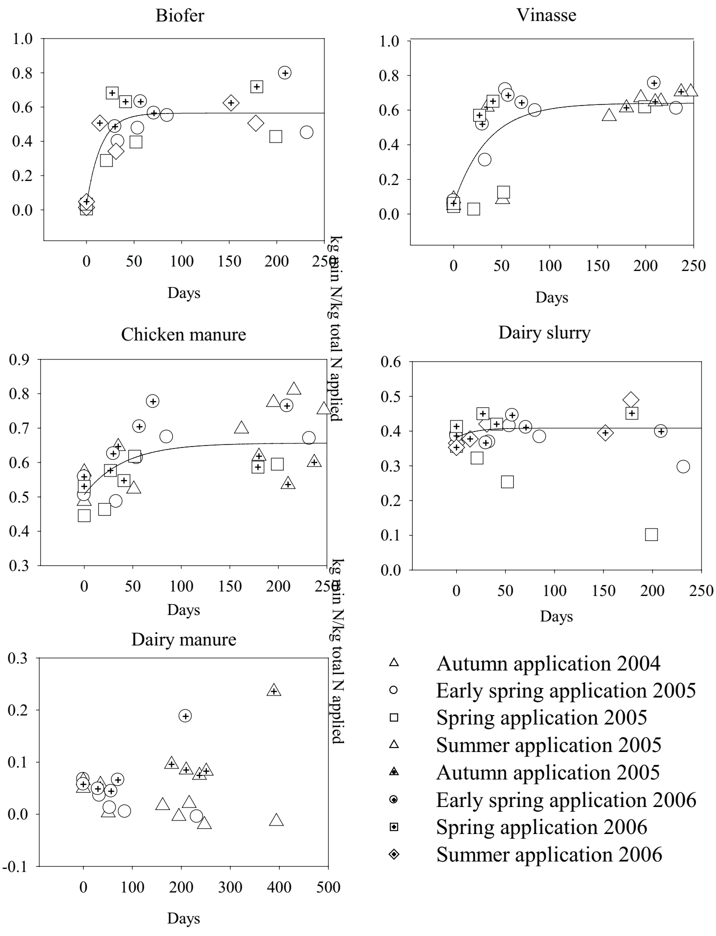


Figure 2. Mineral N plotted against time (days) and heat units (GDD) for the different fertilisers on different application dates

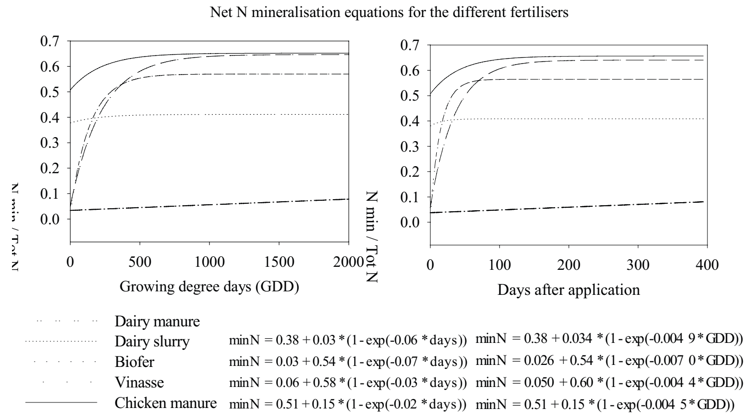


Nitrogen mineralisation from dairy slurry was also negligible and the plant-available fraction of N was practically the same as the initial mineral N fraction. For the other three fertilisers, estimates were made of how fast the organic N mineralised to become plant-available. According to equations in Figure 3, 95% of the organic N in these different fertilisers was in mineral form after 40-100 days depending on fertiliser (Table 2).

Table 2. Time and heat units after application for 95% of total applied N to be converted to mineral form

Fertiliser	Time (days)	Heat units (GGD)
Biofer	43	423
Vinasse	97	666
Chicken manure	63	342

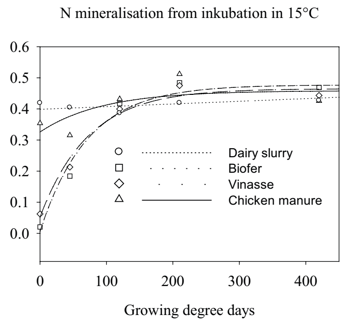
Figure 3. Equations fitted to the experimental data from all applications (except spring application of dairy slurry 2005) for the different fertilisers



When plotted against days, Biofer seemed to have a larger mineralisation rate than Vinasse, but the difference was smaller when plotted against GDD (Figure 3). This may be due to Vinasse being applied in autumn, early spring and spring, whereas Biofer was applied in early spring, spring and summer, when temperatures were higher and conditions thus more favourable for mineralisation. The fertilisers were therefore compared in terms of GDD and converted to days by dividing the number of GDD by a given temperature. A temperature of 10°C meant that it took 42 days before 95% of the N was in mineral form for Biofer, 67 days for Vinasse and for 34 days for chicken manure, using values presented in the heat unit column in Table 2. The reason for the longer period for Vinasse N mineralisation compared with Biofer, despite the similar mineralisation rate, was that more of the N mineralised from Vinasse. A maximum was reached when approximately 65% of the N in Vinasse and chicken manure was in mineral form and about 57% of N in the Biofer seemed to be mineralisable. However, these differences in mineralisation potential between Biofer, Vinasse and Chicken manure were not statistically significant (p=0.22).

Incubation in the laboratory (*Orvendal, 2007;* Figure 4) produced a smaller variation in mineralisation potential between fertilisers than incubation at field temperature (Figures 2 and 3). On the other hand, chicken manure had a lower initial mineral N in the laboratory incubation, and the additional mineralised N was the same proportion of initial mineral N as in the field incubations. For all fertilisers included in the laboratory incubation, net N mineralisation ceased when less than 50% of initial total N was in mineral form. The mineralisation rate up to this level was similar to the field incubations, where similar amounts of N were mineralised after 200 GDD. However, in the field incubations the mineralisation continued after 200 GDD and only ceased after 400-600 GDD.

Figure 4. Course of nitrogen mineralisation in incubations with organic fertilisers at 15°C (*Orvendal, 2007*)



Conclusions

The results indicate that dairy slurry and manure undergo a low, almost negligible, net mineralisation of N after application. Slurry with rather high ammonium content should therefore be applied as close to crop demand as other circumstances allow, whereas dairy farmyard manure with very low mineral N content can be applied off-season. About 55-60% of the N in Biofer mineralised within approximately 40-50 days. The net mineralisation of N in Vinasse was similar or slower and reached about 65% within 60-100 days. Chicken manure had an initial large mineral N content (50%) and about 65% of total N was in mineral form within 30-40 days. According to this, chicken manure can be applied close to peak crop demand, whereas Biofer and Vinasse should be applied at sowing at the latest to meet the N requirements of Swedish spring crops. It might even be favourable to apply Vinasse in advance in order to be sure of utilising the mineralisation potential within the growing season.

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