PREDICTION OF MINERALISATION NITROGEN POTENTIAL FROM ORGANIC RESIDUES TO RYEGRASS AND WHEAT CROPS

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ABSTRACT

To assess the potentially mineralizable nitrogen (PMN) from six organic residues (OR), a laboratory aerobic incubation was conducted in a Cambic Arenosol, consisting of 6 treatments corresponding to: 0, 40, 80, 120, 160 or 200 kg N/ha. The OR tested were: municipal solid waste compost, secondary pulp mill sludge, horn meal, poultry manure, solid phase from pig slurry and composted pig manure. Mineral N evolution was determined at 9 sampling times. Two pot experiments with ryegrass (*Lollium perenne* L.) and wheat (*Triticum aestivum* L) were performed in the same soil to test the reliability of N fate predicted by incubation experiments. Only 80 and 160 kg N/ha treatments were tested, with or without mineral N fertilisation. Data from incubation experiments was very well fitted to the one pool kinetic model proposed by Stanford and Smith. The model showed a better fitting for the residues with a higher proportion of N recalcitrant compounds. Values of PMN (N_0) from the equations obtained by model fitting were well correlated to ryegrass and wheat N uptake. Poultry manure was the most efficient N supplier to crops.

INTRODUCTION

The production of on- and off-farm residues has increased at a very high rate, making it urgent to find an environmental friendly alternative use. These residues can be recycled to agricultural land as a source of both organic matter and nutrients namely nitrogen. This will contribute to the effective utilisation of these on- and off-farm waste materials as valuable resources in agricultural rotations to enhance sustainability and economic competitiveness. This study investigates further the mineralisation of N from six organic residues with different origins (urban, industrial and animal), evaluates their performance as N suppliers when compared to nitrogen mineral fertilisers used for the growth of ryegrass and wheat, and tests the reliability of N fate predicted by laboratory incubation experiments.

MATERIALS AND METHODS

An aerobic incubation experiment was performed using a cambic Arenosol (FAO, 1998) mixed with dried and ground municipal solid waste compost (M), secondary pulp mill sludge (S), horn meal (H), poultry manure (P), solid phase from pig slurry (SP) and composted pig manure (C), at rates equivalent to 0, 40, 80, 120, 160 and 200 Kg N ha^{-1}, based on its total kjeldhal N (TKN) content. Mixtures were placed in black plastic bags, wetted at 70 % soil field capacity, kept at 24±1ºC, and weekly aerated. Nine samplings, were performed at 0, 7, 14, 21, 35, 67, 102, 175 and 244 days after setting, to determine mineral N ($N\text{-}NH_4$+$N\text{-}NO_3$), after extraction with 2 M KCl solution (Mulvaney, 1996). To estimate organic N mineralisation, Stanford and Smith (1972) model ($N_m = N_0*(1\text{-}exp^{-k*t})$ was fitted with the incubation data. N_m represents the mineral N accumulated along time t, N_0 the potentially mineralizable N (PMN) and k the mineralisation rate constant.

***Table 1**. Some chemical characteristics of the six organic residues under study*

	M	S	H	P	SP	C
Kj-N (g kg^{-1})	17.80	42.40	116.70	35.50	17.40	21.70
C/N	15.70	12.65	4.20	12.51	23.80	21.70

Two pot experiments with ryegrass (*Lollium perenne* L) and winter wheat (*Triticum aestivum* L) were conducted, with the same soil and residues. Only 2 doses (80 or 160 kg TKN ha^{-1}, respectively treatments A and B) were tested. Control treatment (A) and half of the pots received a total of 120 kg N ha^{-1} as NH_4NO_3. A bare soil treatment was also tested (B). The remaining pots received only residue as N supply. All pots received a mineral basal dressing except N. Soil was kept at 70% field capacity. Pot experimental data was correlated with data from the equations fitted with the incubation results.

RESULTS AND DISCUSSION

Results from the incubation study were very well adapted to the one pool kinetic model proposed by Stanford and Smith, resulting in the equations: $N_{m(M)} = 0.66 + 3.85*(1-exp^{-0.029*t})$, $N_{m(S)} = 1.44 + 10.27*(1-exp^{-0.071*t})$, $N_{m(H)} = 3.63 + 37.96*(1-exp^{-0.052*t})$, $N_{m(P)} = 10.84 + 13.10*(1-exp^{-0.047*t})$, $N_{m(SP)} = 4.35 + 4.51*(1-exp^{-0.14*t})$ and $N_{m(C)} = 4.63 + 5.48*(1-exp^{-0.12*t})$.

Corresponding mineralization curves of each residue can be observed in figure 1.

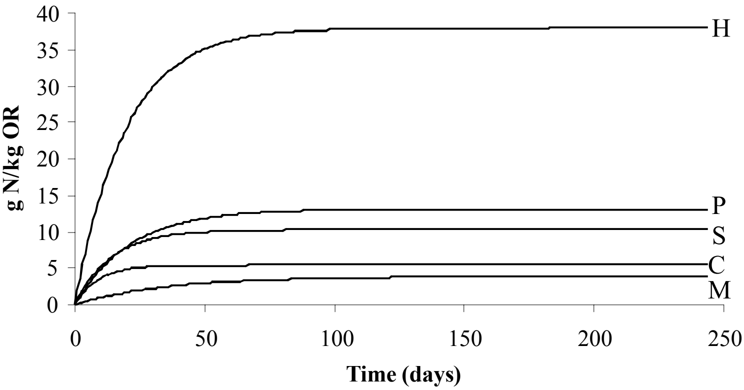

***Figure1**. Net N mineralisation kinetics from the residues added to soil. (0.83<r^2<0.96)*

As expected Active Nitrogen Fraction (ANF= (N_0/N_{Kj})*100) was higher in the poultry manure (36.9%) and lower in the M and S residues (21.6 and 24.2% respectively). In fact, residue characteristics determine its behaviour in the soil, as well as the amount of N that becomes available through mineralization. Actually, Qian and Schoenau (2002) refer that the amount and type of compounds containing N, present in the residues, give rise to a different ability to release mineral N. Moreover, C:N ratio is usually pointed out as one of the most important characteristics regulating N mineralization from organic residues. Except for SP and C residues, all the others showed low C:N ratios, revealing that they are potentially easily mineralised and that immobilization is not likely to occur.

Residues M, S and C presented a fast initial mineralization followed by the stabilization of the mineral N content in the soil, revealing the presence of a high proportion of recalcitrant N compounds and an easily mineralizable fraction. On the other hand, residues from animal origin had a higher active N fraction and therefore mineralized more N and for a longer period.

Concerning data from pot experiments, it can be drawn out that every treatment without mineral nitrogen fertilisation promoted lower plant growth than control. Biomass production was well correlated with N uptake by ryegrass and wheat (0.99<r<1.00), reflecting growth dependence from N supply to the crops.

The most efficient residue in terms of plant N nutrition, for both crops, was poultry manure (figure 2.). The residues SP and H also contributed to ryegrass N nutrition. Wheat plants also benefited from C and H residues application to soil. The less efficient residues to plant nutrition,

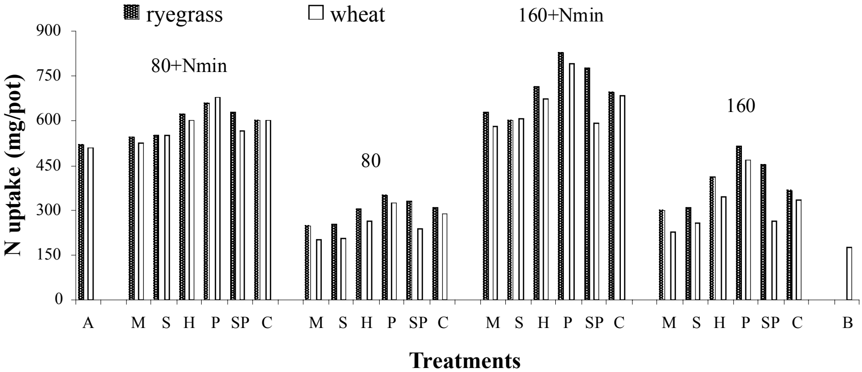

***Figure 2**. N uptake by ryegrass and wheat plants (mg/pot).*

proved to be M and S residues, the ones with a higher proportion of recalcitrant N compounds.

Values of N_0 from the equations obtained by model fitting were well correlated to plant N uptake by ryegrass and wheat, as can be seen in figure 3. The model tested was able to predict, with a high degree of confidence, the availability of N to ryegrass and wheat crops.

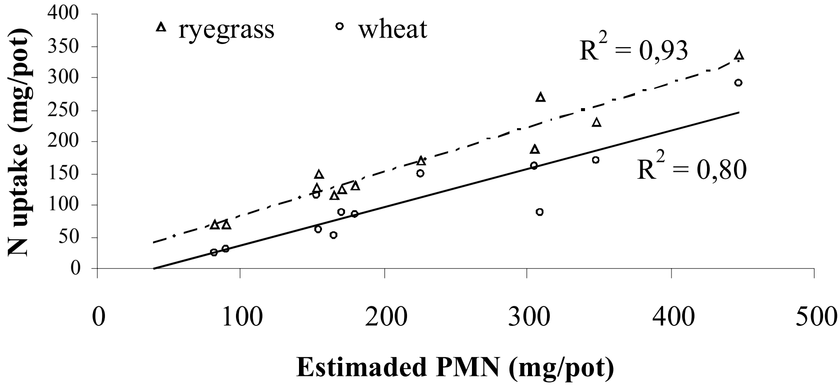

***Figure 3**. Potentially mineralizable nitrogen (PMN) versus N uptake by ryegrass and wheat plants.*

CONCLUSIONS

Nitrogen mineralisation trend observed in the aerobic incubations with all the residues was consistent with experimental data obtained in the pot trials. In fact, all data sets were well correlated, revealing that the model is also well fitted to organic residues mineralization prediction, and not only to soil organic matter. Among the residues tested, poultry manure was the most efficient N supplier to both crops tested, and presents a larger fraction of labile N than the other organic residues used. Municipal solid waste and secondary pulp mill sludge were the less efficient residues to nitrogen supply to crops, probably because they presented the highest proportion of nitrogen recalcitrant compounds.

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