Modelling N mineralization from green manure and farmyard manure from a laboratory incubation study

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Abstract
Predicting N mineralization from farmyard manure (FYM) is more difficult than from crop residues as manures vary greatly in composition. A laboratory incubation experiment was carried out for 98 days at 30º C under aerobic conditions to study the effects of gliricidia (*Gliricidia sepium*), a green manure crop and FYM applied to soil at 5 and 10 g/kg. Application of gliricidia induced N mineralization from the start of incubation process being greater at higher rate of application. Application of FYM increased immobilization of mineral N in soil irrespective of the rates of application; the mineral N in soil was completely immobilized within 2 weeks for the 10 g/kg rate. The initial net immobilization from FYM was limited by availability of N in the soil for the higher rate of application. We used the APSIM SoilN module to simulate N mineralization from these manures. The prediction of N mineralized from gliricidia was better than FYM. Results from the study indicated that existing SOILN module with the pools (FPOOLs) having the same C:N ratio did not work well in predicting the N mineralization from FYM. Poor prediction of N mineralized from FYM could be overcome by modifying the individual pools (FPOOL1, FPOOL2 and FPOOL3) and the pools C:N ratios. The modelling efficiency, a measure of goodness of fit between the simulated and observed data, improved significantly for the modified model.

Key Words
Farmyard manure, nitrogen, mineralization/immobilization, modelling, APSIM.

Introduction
The N mineralization from crop residues is influenced by the concentration of N, hemicelluose, lignin and ratios of chemical components such as C:N. Manures are different from crop residues as they vary greatly in composition (Lekasi *et al.* 2003), being a complex mixture of animal excreta and plant residues, with varied mineralization kinetics ranging from relatively resistant lignin to readily available NH_4^+ and volatile fatty acids (Van Kessel *et al.* 2000). Van Kessel *et al* (2000) reported that manure contains a range of compounds that have rapid or intermediate N mineralization characteristics, or that are strong immobilizers of N and suggested that improved estimates of manure N mineralization may be obtained by considering both the readily available N components and components that strongly immobilize N.

Models differ in the pool structure used to describe the decomposition of organic inputs, with the pools differing in their rates of decomposition. The assumption that all pools have the same C:N ratio may fail to adequately represent the observed behaviour of organic manures. Probert *et al.* (2005) found that predicting N mineralization from such a complex mixture was difficult with the existing models, and reported N mineralization from different feed and faecal materials from Africa as predicted by Agricultural Production Systems Simulation Model (APSIM). The APSIM SoilN module was modified based on varying C and N in different pools that make up the added organic matter. It was shown that the revised model was better able to simulate the general patterns of N mineralized that has been reported for various organic sources. To be able to predict N release from manures more efficiently, it is necessary that the model is flexible enough to simulate the N mineralization from different types of organic manures available in different parts of the world. In this study we used two sources of organic manures viz., green manures (*Gliricidia sepium,* material with low C:N ratio and easily decomposable in soil) vs. the farmyard manure (FYM) from subtropical India which is a more complex mixture than green manure in terms of quality and N mineralization pattern. This study was intended to provide an insight to N mineralization modeling from organic manures which are different in their biochemical properties (as well as C:N ratio) from the materials studied by Probert *et al.* (2005). In this study, the SoilN module of APSIM (v 5.2) has been used.

Materials and methods

Green manures and farmyard manure

The study was conducted using the field-moist soil from the top (0-15 cm) layer of a cultivated Vertisol (Bhopal, India at 23° 18' N and 77° 24' E). The incubation studied N mineralization from green manure (gliricidia) and FYM, using two rates of application, 5 g/kg and 10 g/kg. The properties of the gliricidia and FYM are given in Table 1.

Table 1. Biochemical composition of the organic manures used for simulation study.

Treatment	Overall C/N ratio	Proportion of C in FPOOLs (%)			C:N ratio of FPOOLs		
		Pool 1	Pool 2	Pool 3	Pool 1	Pool 2	Pool 3
FYM (UM)	30	20	70	10	30	30	30
FYM (M	30	9	73	18	50	44	12

* UM: unmodified; M: modified

Analytical procedures

The soil used in the incubation study had pH 8.1(in 1:2.5 soil:water suspension), organic C content of 5.1 g/kg, a C:N ratio 9.6, and inorganic N (NH_4-N and NO_3-N) content of 30 mg/kg. Total N was determined using the semi-micro Kjeldahl method of Bremner and Mulvaney (1982). Total C in organic materials was estimated by the weight loss on ignition. Lignin in the organic materials was determined using the acid detergent fibre (ADF) method as outlined by Rowland and Roberts (1994). Total soluble polyphenols in organic materials was determined by the Folin-Ciocalteau method (Constantinides and Fownes 1994).

Laboratory Incubation experiment

Finely ground gliricidia twigs (leaves and succulent stem) and FYM (collected from a typical Indian farm) were applied to soil at two rates of application, 5 g/kg and 10 g/kg on an oven dry-weight basis.
For each treatment, a sample of 500 g soil was hand mixed with 2.5 g or 5.0 g of organic material (depending upon the rate of application), then transferred to a plastic bottle. The control treatment was soil without added organic materials. The treatment mixtures were maintained at field capacity throughout the incubation period by replacing any loss of water with the appropriate volume of distilled water at every sampling. The soil and organic material mixtures were incubated at 30±2 °C for 14 weeks in duplicate in a laboratory incubator. Soil samples were taken at 0, 1, 2, 4, 6, 8, 10, 12 and 14 weeks and analyzed immediately for inorganic N (NH_4-N + NO_3-N) using 2M KCl extraction followed by distillation. Net N mineralized during the incubation process was calculated as follows:

(Net N mineralized from organic materials)$_t$ = (Mineral N in the treatment – mineral N in control)$_t$.

Modelling decomposition of organic materials and release of nitrogen

Description of the APSIM SoilN module

The APSIM SoilN module (APSIM v 5.2) represents the decomposition of organic inputs as influenced by the quality of organic inputs. The effect of changing the pool structure and C:N ratio of individual pools on decomposition of organic materials has been described by Probert *et al.* (2005). The APSIM SoilN module was modified so that the three pools that constitute added organic matter could be specified in terms of both the fraction of C in each pool and also their C:N ratios. The model was parameterized by associating the model parameters with measured properties (the pool that decomposes most rapidly equates with water-soluble C and N; the pool that decomposes slowest equates with lignin-C). Then the model was evaluated for N mineralized from gliricidia and FYM from a laboratory incubation study.

Model evaluation

The performance of APSIM simulation for prediction of net N mineralized from the application of these high C:N ratio materials was evaluated using two statistics: (i) the root mean square error (RMSE), and (ii) the modelling efficiency (EF) (Smith *et al.* 1996).

Results and discussion

Nitrogen mineralization from gliricidia and farmyard manure

Total C content of the gliricidia was 40, while total N was 3.72% and hence, the C:N ratio of 11. The lignin content of the materials was 6.5% and that of polyphenols was 1.5%. The C:N ratio of FYM used for the study was 30 with lignin and polyphenols content being 11 and 1.22%. The C:N ratio of the water soluble component of FYM was 50. The application of gliricidia caused net N mineralization in soil which increased with time and with the rates of application (Figure 1). With increase in incubation period the difference in N mineralized between two rates of application became bigger. At the end of the incubation period, about 65% of applied N was mineralized for the 5 g/kg rate while the N mineralized from the 10 g/kg rate was 54%.

With increase in incubation period, the amount of N immobilized from FYM was greater from the higher rate of application, and N immobilization continued till the end of the incubation period (Figure 1). The amount of N immobilized from the application of low rate (5 g/kg) of FYM was limited by C availability where as at higher rate (10 g/kg), it was limited by mineral N. Increasing the rates of application of FYM caused more immobilization of available N in soil system indicating utilization of available N by microbes from the soil environment when decomposing organic materials with high C:N ratio (Alexander 1977).

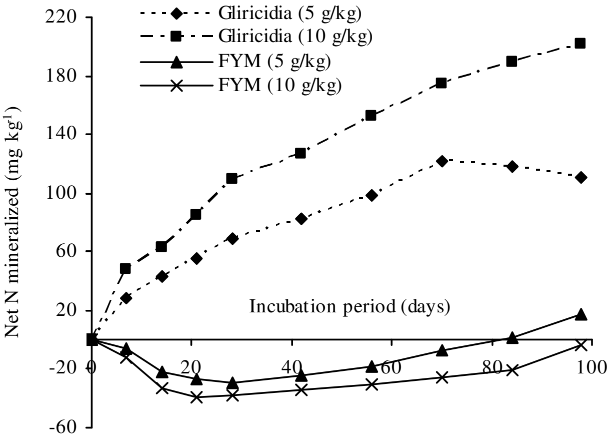


Figure 1. Net N mineralization from gliricidia and FYM under different rates of application.

Modelling N mineralized from gliricidia and farmyard manure

The comparison of simulations with measured data for different rates of application gliricidia is shown in Figure 2 (a,b). The pattern of N mineralized as seen in the observed data was well presented by the model. The amount of N mineralized as predicted by the model from the 10 g/kg rate of gliricidia was twice the amount N mineralized from the application of 5 g/kg. The model will predict that N mineralization from gliricidia depends on its C:N ratio, so that net N mineralized is directly proportional to rate of application. But this trend was not obtained from the observed data. Based on the pattern of N mineralization and the statistics used for the evaluation of the model the goodness of fit was quite satisfactory for gliricidia (EF = 0.87).

The simulation of N mineralized from different rates of application of FYM was presented in Figure 3a and 3b. Assuming that added C in the three FPOOLs of the model is always in the proportion of 0.2-0.7-0.1 (as defined in the model for crop residues and roots), the simulation of N immobilized from both the rates of

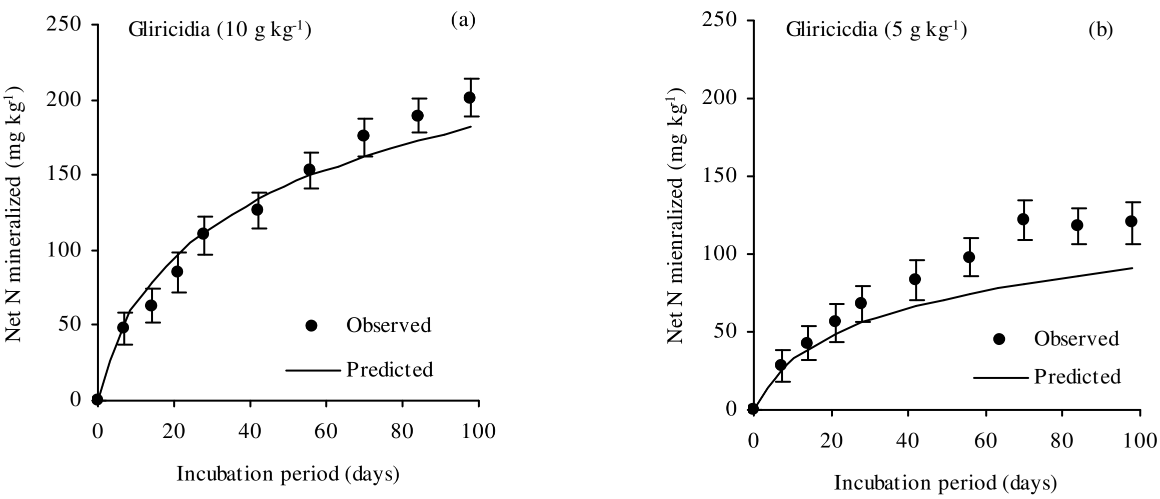
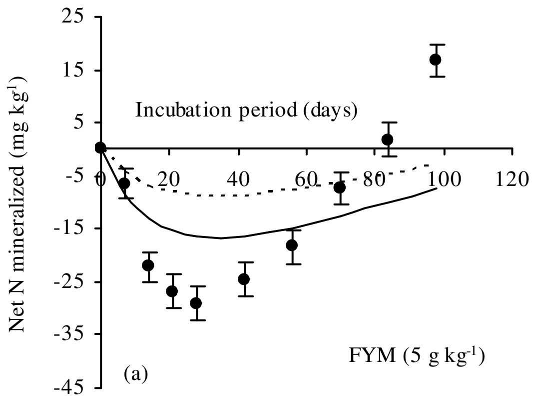


Figure 2. Net N mineralization from gliricidia under different rates of application as predicted by the model.



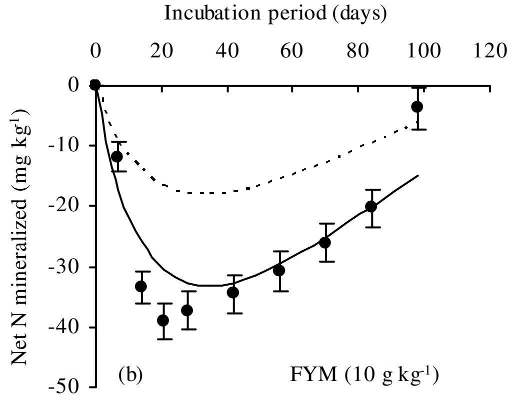


Figure 3. Net N mineralization from FYM at two rates of application. Experimental data shown as symbols with bar representing ± standard errors. The dotted line is for the un-modified model, where all organic material is assumed to decompose with the same C:N ratio; the continuous line is for the modified model with different C:N ratio in each FPOOL. The parameters used to specify the proportion of C and C:N in the three FPOOLs are given in Table 1.

FYM as predicted by the model (un-modified version) was shown in Figure 3. The goodness of fit was very poor for both the rates of application (RMSE = 14.69, EF = 0.05). When "FPOOLs" were specified in similar manner to that suggested by Probert *et al.* (1995) (see Table 1), the goodness of fit was better than the unmodified model (RMSE = 9.24, EF = 0.62).

The model assumes the water soluble component of C and N as FPOOL1 and thus, from the analytical results, it was possible to determine the proportion of C in this pool and its C:N ratio (Table 1). This enabled us to achieve an acceptable fit to the observed data. We also assume that acid detergent lignin, which is proximate analysis of lignin, equates to FPOOL3, permitting the fraction of C in this pool to be estimated. The fraction of C in FPOOL2 was found by difference. Since, the overall C:N ratio (on a total dry matter basis) is also known, the only missing information was the distribution of water insoluble N between FPOOL2 and 3. A series of simulations were carried out for the FYM with different combinations of C:N in the two pools. To obtain a goodness of fit shown in Figure 3, the manure required C:N ratio of FPOOL1 to be set to 50, FPOOL2 to 44, with the corresponding C:N ratio in FPOOL3 of 12. For FYM, the goodness of fit is substantially better in the modified model than the unmodified one.

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