Modelling N mineralization from high C:N rice and wheat crop residues

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Abstract
The processes of N mineralization and immobilization which occur in agricultural soils during decomposition of crop residues are important for N dynamics in cropping systems. A laboratory incubation experiment was carried out for 98 days at 30º C under aerobic conditions to study the effects of rice (*Oryza sativa*, L.) and wheat (*Triticum aestivum*, L.) straw applied at 5 and 10 g/kg in the presence or absence of additional N (as urea). The study showed an interactive effect between the rate of application of the residues and additional N. We used the APSIM SoilN module to simulate the mineralization of N from crop residues and compared the predictions with the observed data from our incubation study. Model performance was satisfactory, and the model was able to simulate the observed interaction between rate of application of residue and added N.

Key Words
Nitrogen, mineralization/immobilization, rice straw, wheat straw, simulation modelling, APSIM.

Introduction
In the absence of recent additions of fresh organic matter, soils generally exhibit mineralization during incubations. When residues are added, the net mineralization due to the added materials can be estimated as the difference between the amended soil and a control (without amendment). Residues with low C:N ratio tend to exhibit net N mineralization, while residues with high C:N ratio exhibit immobilization (Van Kessel *et al.* 2000; Qian and Schoenau 2002). In farming systems where the straw remains on the field after harvest, its rapid decomposition is important to minimize negative effects on the following crops caused by N immobilization (Cheshire *et al.* 1999; Henriksen and Breland 1999). Yield depression following straw incorporation has been mitigated by adding inorganic N (Azam et *al.* 1991). Strategies for management of high C:N ratio residues could be improved though the use of simulation models. The objective was to evaluate the performance of APSIM to simulate the N mineralization pattern from high C:N ratio crop residues (rice and wheat straw) using a dataset from a laboratory incubation experiment that investigated the effects of rate of addition of residues with high C:N ratio, and added N, on the net N mineralization.

Materials and methods
Soil and crop residues
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 immobilization from two crop residues, rice and wheat straw, using two rates of application and in the presence and absence of added N. The C:N ratio of rice was 86 and that of wheat was 79.

Analytical procedures
A portion of field-moist soil was taken for laboratory incubation, while another portion was air-dried, crushed to pass through a 2 mm sieve, then stored in an air-tight plastic container at room temperature. A sub-sample of this material was finely ground to pass 100-mesh sieve. 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 using the semi-micro Kjeldahl method of Bremner and Mulvaney (1982). Total C in organic materials was estimated by the weight loss on ignition (Nelson and Sommer 1982).

Laboratory Incubation experiment

Finely ground wheat and rice straw were applied to soil at two rates of application, 5 g/kg and 10 g/kg on an oven dry-weight basis. The amount of urea-N added was enough to raise the wheat straw N to approximately 2% on dry weight basis. This required the addition of 66 mg N/kg soil where the materials were added at low rate of addition i.e. 5g/kg, and 132 mg/kg at the high rate.

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. For each treatment urea-N was added as appropriate. 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°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 (Bremner 1965). 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)$_t$ - N added.

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

N mineralization from rice and wheat straw under laboratory incubation

Similar results were obtained for N mineralization from both rice and wheat straw for both the rates of application and where urea-N was added (in Figure 1 only the data for the rice treatments are shown). Application of rice straw at 5 g/kg reduced the mineral N in the soil to zero (Figure 1). Increasing the rate of rice straw application increased the time that the mineral N in soil was maintained at very low concentration. When urea-N (66 mg N/kg) was added along with 5 g/kg of straw, the mineral N in soil was not reduced to zero.

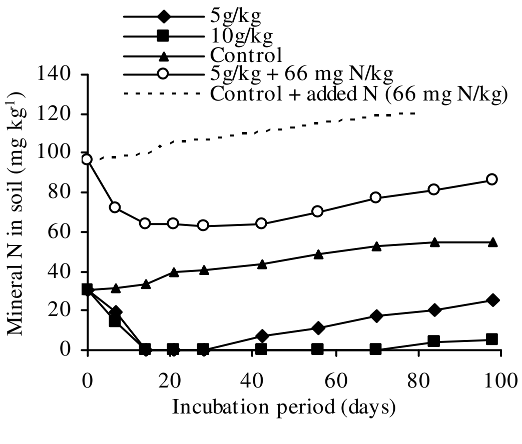

Figure 1. Nitrogen mineralization from rice straw under different rates of application. The doted line for control with 66 mg N/kg assumes all added N remain in the system.

In the absence of added N, application of 5 g/kg rice straw caused rapid immobilization which reached about 40 mg N/kg by 28 days (Figure 2a). At this time there was no mineral N in these systems (Figure 1). The disappearance of mineral N in the soil system was caused by microbial immobilization as reported by Recous *et al.* (1995). Increasing rates of straw addition increased both the amount of N immobilized and the length of the period of net immobilization (Figure 2b).

For the 5 g/kg rate of application of rice straw, adding additional N caused a small increase in the maximum amount of N immobilized (Figures 2a, c). There was no mineral N in the system at two weeks when straw was applied alone, whereas when N was added, mineral N was present throughout the incubation (Figure 1). The results obtained in our study also showed that additions of N had significant effects on net amounts of N immobilized as a result of added straw (Figure 2d). Similar results were obtained for wheat.

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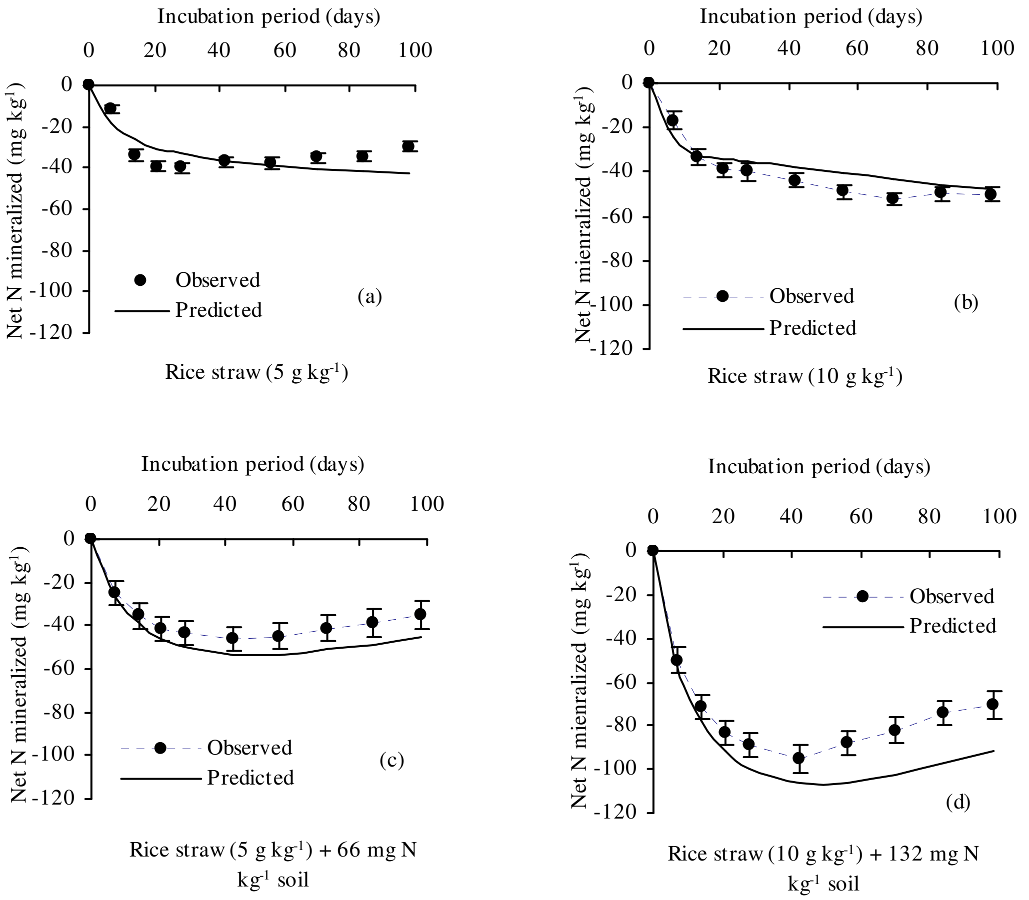

Figure 2. Simulation of net N mineralized from rice straw at (a and b) different rates of application, and (c and d) in presence of urea-N. Vertical bars represent ±standard errors.

Simulation of N mineralized from rice and wheat straw

We used the model to simulate the effect of rates of organic matter and N application, on N mineralization from high C:N ratio materials (rice and wheat straw). The APSIM model predicted N mineralization from high C:N rice straw satisfactorily under different rates of application of straw in presence and absence of added N (Figure 2). Similar observations were also recorded from wheat straw. However, in presence of added N, the model prediction was better than for the treatments with residue alone (RMSE = 10.23 and EF = 0.79) values. The model assumes that the rate of decomposition of added organic materials is limited when there is inadequate mineral N in the system to satisfy the immobilization demand. Even so, it is shown that the model predicted satisfactorily the observed behaviour of the system. The modelling efficiency, a measure of goodness of fit between the simulation and observed data, was 0.82 for the treatments in the incubation study.

Conclusion

From the incubation experiment, the high C:N ratio rice and wheat straw caused immobilization of soil mineral N, to the extent dependent on the rate of application of the straw, and the soil inorganic N availability and the APSIM model predicted it satisfactorily.

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