

Original Research Article

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Nitrogen Transformation for Paddy Fields under Aerobic Soil Condition

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ABSTRACT

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The widely adopted Alternate Wetting and Drying (AWD) irrigation for rice production is increasingly needed to investigate for assessing nitrogen fate in the soil. An experiment was conducted under aerobic soil conditions to study Nitrogen (N) transformations. The simple numerical analytical model used to simulate urea, ammonical nitrogen (NH₄-N) and nitrate nitrogen (NO₃-N) concentration in experimental plot. Simulation of urea concentration decreased as 2 %, ammonical nitrogen and nitrate nitrogen concentration increased as 9 % and 9.8 % compared to observation. The results reflect the urea concentration is high in 37.5 cm soil depth, ammonical nitrogen and nitrate nitrogen concentration is high in 7.5 cm soil depth.

Introduction

Nitrogen is universally deficient in majority of the agricultural soils and successful arable farming is impossible without the use of nitrogenous fertilizers. Moreover, nitrogen fertilization aims at a high economic return of the investment through optimized crop yield and quality. Although nitrogen, from a quantitative point of view, the most important nutrient in crop production in comparison with phosphorus (P) and potassium (K), its efficiency is low for crop production. Fertilizers upon application to soil are subjected to numerous reactions, transformations and N loss under paddy

fields. In view of the high cost of nitrogen fertilizer, it is important to improve the N utilization efficiency for crop production with the objective to reduce cost of crop production.

Urea is the major N fertilizer used for optimum crop yields all over the world. Addition of urea in soil, by virtue of its hydrolysis, increases soil pH thereby causes tremendous ammonia volatilization losses (Hamid *et al.*, 1998). Also the fields under alternate flooding and drying, a significant amount of nitrogen is lost due to nitrification followed by denitrification as a result of oxidation and reduction (Burford and

Bremner, 1975). Reduction in such losses still becomes easily manageable if their reactions and transformations are clear and easily understood.

Water shortage has constrained both economic and agricultural development in India. Lowland rice fields have relatively high water requirements and their sustainability is threatened by increasing water scarcity (Bouman and Tuong, 2001). Many water-saving irrigation technologies for rice production have been developed and promoted to enhance water productivity and to reduce water use. The most widely promoted water-saving technology for rice so far is alternate wetting and drying (AWD) also referred as alternate submergence–nonsubmergence (Feng *et al.*, 2007). The basic feature of this method is to irrigate so that the soil alternates between periods of standing water and damp or dry soil conditions from approximate 30 days after crop establishment up to harvesting (Moya *et al.*, 2004). AWD has been widely adopted in northwest India and can now be considered the common practice of lowland rice production (Li and Barker, 2004).

Few studies had showed the mechanisms of nitrogen transformation in rice system of AWD. During the aerobic period of alternate wetting and drying, $\text{NH}_4\text{-N}$ is rapidly nitrified due to the availability of oxygen in the soil pores. Nitrification provides the substrate ($\text{NO}_3\text{-N}$) for denitrification when the soil is reflooded (Broadbent 1971). The nitrogen losses increased because of nitrification–denitrification processes induced by drying and wetting cycles (Buresh *et al.*, 1993) and AWD rice systems have greater potential for nitrogen losses (Vial 2007). AWD can enhance nitrogen leaching with potential implications for water quality. Moreover, the forms of nitrogen, i.e., $\text{NO}_3\text{-N}$ and $\text{NH}_4\text{-N}$ losses through ammonia volatilization and

leaching are quite different in limited studies. It is needed to understand the effect of AWD on nitrogen leaching losses and nitrogen use efficiency of rice. Therefore, in this paper, experiments were conducted to demonstrate the different form of nitrogen and nitrogen use efficiency of AWD.

Materials and Methods

This study conducted at Agricultural engineering college and research institute, Tamilnadu Agricultural University (TNAU), Kumulur used and an experimental plot size of 7 m × 5.7 m. Soil samples were collected from the experimental plot at different soil depths of 7.5 cm, 22.5 cm and 37.5 cm for urea, $\text{NH}_4\text{-N}$ and $\text{NO}_3\text{-N}$ concentrations. For this study data collected from experimental plot with an interval of ten days for the whole period. Table 1 represents the physical and chemical properties of the experimental plot. Total Nitrogen recommended for paddy is 175 kg/ha. The Tensiometer was installed at 22.5 cm for the observation of soil moisture tension. Irrigation was given whenever the soil moisture tension reached 20 KPa in the Tensiometer.

Ammonical nitrogen ($\text{NH}_4\text{-N}$) and nitrate nitrogen ($\text{NO}_3\text{-N}$)

Weigh 10 g of soil and transferred into a 100 ml of shaking bottle. Add 100 ml of 2M KCl solution was shaken for 1 hour by means of mechanical shaker. Filter through a Whatman No.1 filter paper. Pipette out of 20 ml of the filtrate into 500 ml of distillation flask. Add 200 ml of distilled water, 1ml of liquid paraffin, few glass beads and then add pinch of freshly ignited MgO. Immediately close the distillation flask, distill the contents at a steady rate collecting the liberated ammonia in 250 ml beaker containing 25 ml of 2% boric acid with double indicator. Continue the distillation for about 30 minutes (or) until 100

ml of distillate is collected in the beaker. Ammonia collected in the beaker which has been titrated against the standard 0.02 N H₂SO₄ and from the titrate value calculate the ammonical nitrogen present in the soil.

After distilling ammonical N contained in the solution, cool the contents in the distillation flask. Add pinch of devarda's alloy and continue the distillation. The evolving ammonia is absorbed in 2 % of boric acid. Titrate the ammonia collected against the standard 0.02 N H₂SO₄ and from titrated value nitrate nitrogen present in the soil was calculated.

Analytical model

All N transformations take place in aerobic condition and are approximated by first-order kinetics, governing differential equations, describing the rate of change in concentration of various N species are described below. It may be noted that in a given spatial element of the soil, most of these reactions may occur simultaneously, depending on the energy source, oxygen level, soil water content, temperature and other dependent variables. Furthermore, the rate may not be constant but vary with the above-mentioned variables.

Urea hydrolysis

When urea is broadcast on experiment field soil, it is hydrolyzed to NH₄⁺ and HCO₃⁻ ions. The process of urea hydrolysis can be represented by a first-order reaction as follows:

$$UNH_4 = U (1 - e^{-K_h t})$$

U is the amount of fertilizer (urea) applied (kgNha⁻¹)

UNH_4 is the amount of ammonium produced during urea hydrolysis process (kgNha⁻¹)

K_h is the rate constant for urea hydrolysis (per day)

t is the time (day).

Nitrification

The conversion of NH₄⁺ to nitrate is called nitrification. In flooded rice soils, the substrates for nitrification are provided in the form of ammonium ions (NH₄⁺) produced during urea hydrolysis. Nitrification in the aerobic condition follows the first-order rate equation given by

$$UNO_3 = UNH_4 (1 - e^{-K_n t})$$

UNO_3 is the nitrate produced during nitrification (kgNha⁻¹)

UNH_4 is the ammonium produced during urea hydrolysis or the mineralization of organic N (kgNha⁻¹)

K_n is the nitrification rate constant (per day)

The reaction rate constant found from Risk Solver Platform software, which is an add-on for the MS-Excel. In this software, we need to provide the range of reaction rate constant with in which search operation is to be executed and estimate the quantities of urea, NH₄-N, NO₃-N.

Results and Discussion

The model results for the different N-transformation (urea, ammonical nitrogen and nitrate nitrogen) at different depths are presented in Figure 1. Observed and Simulated values of rate constants are found for specific N-transformations are given in Table 2.

It is observed from Table 3 that the estimated reaction rate constant value for urea

hydrolysis and nitrification. The reaction rate constant value is lower at 7.5 and 22.5 cm and higher at 37.5 for both processes.

It is seen that the (Fig. 1) simulated values are in reasonable agreement with the experimental values. Simulation shows that decreased urea concentration 2 %, ammonical nitrogen and nitrate nitrogen concentration increased as 9 % and 9.8 % compared to observation. The results reflect the urea concentration is high in 37.5 cm soil depth, ammonical nitrogen and nitrate nitrogen concentration is high in 7.5 cm soil depth. The model development and data input are such that simulations can be carried out

simultaneously for a wide range of soil types, fertilizer and irrigation applications. The major assumption of the model is that conversion of the different forms of N in the soil–water–plant system follows first-order kinetics. Higher loss of N immediately after the application of fertilizer is due to the increase in concentration of dissolved N in soil solution. The present studies the rate constants are constant though the numerical values depend on the number of microorganisms participating in the process. Therefore, development of functional relations between rate constants and environmental variables may lead to better predictions of N-transformation processes

Table.1 Physical and chemical properties of the soil

Character/property	Values
Sand (%)	68
Silt (%)	20
Clay (%)	12
Textural Class	Sandy loam
pH	8.18
Electrical Conductivity (dS m ⁻¹)	0.31
Organic Carbon (%)	0.25
Available Nitrogen (Kg ha ⁻¹)	134

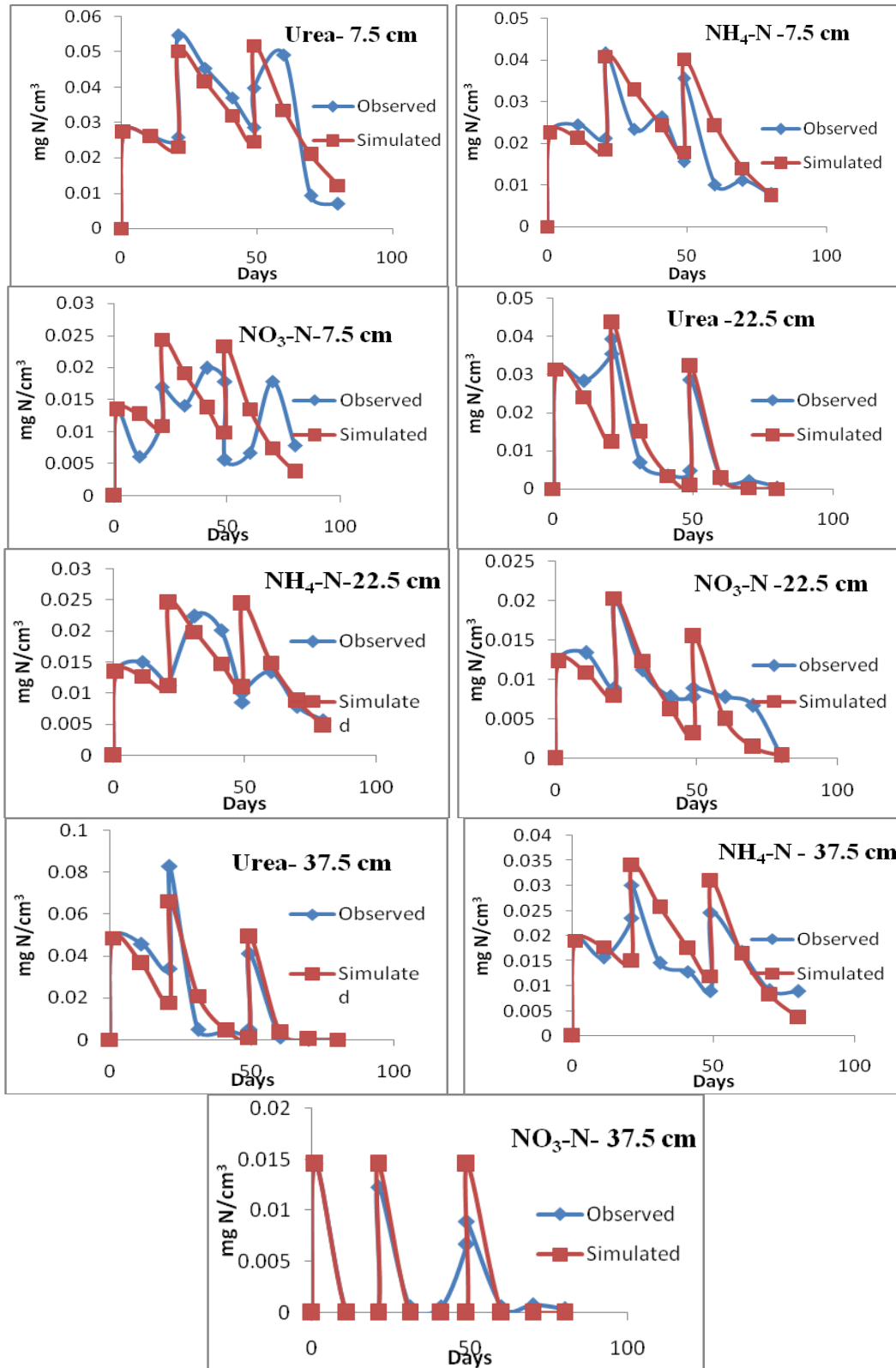
Table.2 Observed and simulated values for n transformation

Processes	Observed (Kg N ha ⁻¹)			Simulated (Kg N ha ⁻¹)		
	7.5 cm	22.5 cm	37.5 cm	7.5 cm	22.5 cm	37.5 cm
Urea concentration	34.963	18.320	26.768	34.263	16.567	24.842
Ammonium concentration	23.998	13.906	18.425	26.352	16.039	20.026
Nitrate concentration	13.572	10.553	4.565	15.219	9.566	4.370

Table.3 Reaction rate constant for different N-transformation processes

Processes	Reaction rate constants (per day)		
	7.5 cm	22.5 cm	37.5 cm
Urea hydrolysis	0.0007	0.0040	0.0043
Nitrification	0.0009	0.001	0.01

Fig.1 Comparison of simulated and measured urea, NH₄-N and NO₃-N concentration at different soil depth of 7.5 cm, 22.5 cm and 37.5 cm in paddy plots under AWD



In conclusion, the analytical model presented in this paper is simple and comprehensive as it includes all the important N-transformation (urea, ammonical nitrogen and nitrate nitrogen) that occur in both soil and flood water zones in paddy fields. The model is applicable under a wide range of field, environmental and management conditions for paddy.

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