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Use of urease inhibitors to reduce ammonia loss following application of urea to flooded rice fields

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Abstract

Ammonia (NH_3) volatilization is an important mechanism for nitrogen (N) loss from flooded rice fields following the application of urea into the floodwater. One method of reducing losses is to use a urease inhibitor that retards the hydrolysis of urea by soil urease and allows the urea to diffuse deeper into the soil. The two chemicals that have shown most promise are phenylphosphorodiamidate [PPD] and N(n-butyl)thiophosphorictriamide [NBPT], but they seldom work effectively. PPD decomposes rapidly when the pH departs from neutrality, and NBPT must be converted to the oxygen analogue for it to be effective. Our field studies in Thailand show that the activity of PPD can be prolonged, and NH_3 loss markedly reduced, by controlling the floodwater pH with the algicide terbutryn. A mixture of NBPT and PPD in the presence of terbutryn was even more effective than PPD alone. It appears that during the time when the PPD was effective, NBPT was being converted to the oxygen analogue. The combined urease inhibitor - algicide treatment reduced NH_3 loss from 10 to 0.4 kg N ha^{-1}.

Introduction

Currently, urea is the main N fertilizer used for flooded rice in Asia (Stangel and Harris, 1987), but it is not used efficiently (De Datta, 1987). Recoveries of urea N by the crop can be as low as 10%, although usual farmers' practice in Asia results in 30 to 40% recovery in the plant. The reason for the low recoveries is that much of the applied N is lost from the plant - soil system by gaseous emission (De Datta et al., 1989; Fillery et al., 1984; Freney et al., 1990; Simpson and Freney, 1988). The losses occurred quickly and appeared to be almost entirely in the form of NH_3 (4% to 56% of the applied N) and dinitrogen (3% to 50% of the applied N) resulting from volatilization and denitrification. Ammonia is lost following the application of urea because of the catalytic reaction of soil urease and the high pH of the floodwater.

One approach to reducing NH_3 volatilization is to find compounds that inhibit urease activity, thus allowing the urea to move into the soil before hydrolysis. The NH_3 released would then be retained by the soil. The urease inhibitors most commonly tested in flooded rice fields are phenylphosphorodiamidate [PPD] and N-(n-butyl)thiophosphorictriamide [NBPT]. Little success has been achieved with these compounds (Buresh et al., 1988 a, b) because PPD is rapidly hydrolyzed under the alkaline conditions generated in the floodwater by photosynthetic algae (Hauck, 1984), and NBPT has to be converted to the oxygen analogue [N (nbutyl) phosphorictriamide] before it is effective (Creason et al., 1990). In many situations much of the urea has been hydrolyzed before the conversion of NBPT has occurred. This paper describes experiments that show that PPD and NBPT can be used to prevent NH_3 loss in flooded fields.

Experimental

The experiment was conducted on a clay soil at the Suphanburi Rice Experiment Station in the Central Plain region of Thailand. The soil contained 3.7% organic matter, had a total N concentration of 0.16%, a cation exchange capacity of 28cmol(+)kg^{-1}, a clay content of 63%, and was covered with 0.05 m floodwater. The field was planted with 21 day old rice seedlings (Oryza sativa var. Suphanburi 90) on 2March 1992 in hills at 0.20 m spacing. The experiment was carried out in 4 m × 4 m plots with three replicates in a randomized block design. Urea was surface broadcast onto all plots on 5 March 1992 to give 60kgNha^{-1}. The treatments imposed were: on 2 March, NBPT at 0.5%, 1% and 2%; on 5 March, Control (no inhibitor), NBPT at 0.5%, 1% and 2%; PPD at 0.5%, 1% and 2%; NBPT at 0.5% + PPD at 0.5%; NBPT at 1% + PPD at 0.5%; NBPT at 2% + PPD at 0.5%. The inhibitors, added as a percentage of the weight of urea, were dissolved in water and sprayed onto the surface of the floodwater before the addition of urea. The potential for NH_3 loss from these plots was determined from 2-hourly measurements of floodwater pH, temperature and ammoniacal N concentration by a bulk aerodynamic method (Freney et al., 1985). This method was calibrated from measurements made within a circular area of 50 m diameter in an adjacent field, where the vertical NH_3 flux was determined with NH_3 samplers (Leuning et al., 1985). With the exception of the circular area, all plots received applications of the algicide terbutryn [2(tert-butylamino)-4-(ethylamino)-6-(methylthio)-s-triazine] (0.2 mg active ingredient L^{-1} floodwater) at four day intervals.

Results and discussion

In the absence of algicide the floodwater pH rose rapidly to 8.7, and showed the diurnal cycling pattern characteristic of flooded rice fields (Mikkelsen et al., 1978). The maximum floodwater pH reached was 9.3 (Figure 1). Addition of terbutryn maintained the floodwater pH below 8 for five days after application, and during that period the typical diurnal pH cycling

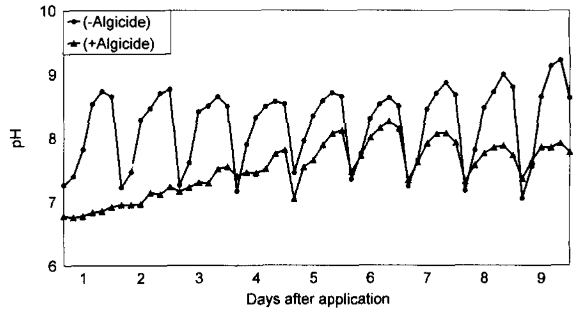

Fig. 1. Effect of algicide treatment on pH of floodwater at Sulphanburi.

pattern did not occur (Figure 1). After that time, even though additional terbutryn was applied, the pH increased and the normal pattern of pH increase during the day and decrease at night occurred. It appears that the photosynthetic algae in the floodwater adapted to the algicide and subsequent additions of the algicide failed to completely suppress the growth of the algae. However, in the presence of terbutryn the pH of the floodwater never exceeded 8.3.

In the control treatment, the ammoniacal N concentration of the floodwater rose to 1g N m^{-2} (Figure 2). All urease inhibitor treatments in the presence of terbutryn maintained the ammoniacal N concentration below that value, and increasing the rate of inhibitor application from 0.5% to 2% had no significant effect on the rate of urea hydrolysis. Of all the inhibitor treatments NBPT was least effective, whether applied three days before, or at, the time of application of urea. In

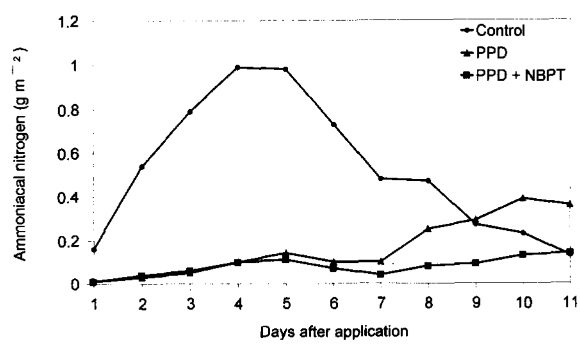

Fig. 2. Effect of urease inhibitors and algicide on ammoniacal nitrogen in floodwater following the application of urea.

the presence of PPD and terbutryn, the ammoniacal N concentration remained below 0.1 g N m^{-2} for 7 days after fertilizer application, and only approached 0.4g N m^{-2} after 10 days (Figure 2). Apparently PPD retained its effectiveness during the period when terbutryn controlled the growth of algae and the pH remained low.

A mixture of NBPT and PPD in the presence of terbutryn was even more effective than PPD+terbutryn in preventing the hydrolysis of urea. It appears that during the time when the PPD was effective, NBPT was being converted to the oxygen analogue. Then as the activity of PPD started to decline the soil urease was inhibited by the oxygen analogue of NBPT (Figure 2). It was expected that the early addition of NBPT would allow it to be converted to the oxygen analogue before the addition of urea, and that this treatment would be more effective than the NBPT treatments added at the same time as urea. However, it appears that algae are necessary to provide sufficient oxygen for the conversion; until urea was added to the floodwater no algal growth was apparent. At the time of conducting the field experiment we were unable to purchase the oxygen analogue of NBPT for use as one of the treatments.

In the absence of the algicide and urease inhibitors 10 kg of applied N per hectare was lost as NH_3 following application of urea into the floodwater. The addition of PPD and terbutryn reduced NH_3 loss to 0.6 kg N ha^{-1}, while the NBPT + PPD + terbutryn treatment resulted in a loss of only 0.4kgNha^{-1}. It is apparent that under the right conditions PPD and NBPT can be used to reduce urea hydrolysis and NH_3 loss from flooded rice fields.

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References

Buresh R J, De Datta S K, Padilla J L and Samson M I 1988a Agron. J. 80, 763-768.

Buresh R J, De Datta S K, Padilla J L and Samson M I 1988b Soil Sci. Soc. Am. J. 52, 856-861.

Creason G L, Schmitt M R, Douglass E A and Hendrickson L L 1990 Soil Biol. Biochem. 22, 209-211.

De Datta S K 1987 *In* Efficiency of nitrogen fertilizers for rice. Eds. J R Freney, R Wetselaar, A C F Trevitt and J R Simpson. pp 27-41. International Rice Research Institute, Los Banos, Philippines.

De Datta S K, Trevitt A C F, Freney J R, Obcemea W N, Real J G and Simpson J R 1989 Soil Sci. Soc. Am. J. 53, 1275-1281.

Fillery I R P, Simpson J R and De Datta S K 1984 Soil Sci. Soc. Am. J. 48, 914-920.

Freney J R, Leuning R, Simpson J R, Denmead O T and Muirhead W A 1985 Soil Sci. Soc. Am. J. 49, 10491054.

Freney J R, Trevitt A C F, De Datta S K, Obcemea W N and Real J G 1990 Biol. Fertil. Soils 9, 31-36.

Hauck R D 1984 *In* Nitrogen in Crop Production. Ed. R D Hauck. pp 551-560. Am. Soc. Agron., Madison.

Leuning R, Freney J R, Denmead O T and Simpson J R 1985 Atmos. Environ. 18, 1583-1592.

Mikkelsen D S, De Datta S K and Obcemea W N 1978 Soil Sci. Soc. Am. J. 42, 725-730.

Simpson J R and Freney J R 1988 *In* Int. Symp. on Urea Technol. and Utilization. Eds.EPushparajah, AHusin and A T Bachik. pp 281-290. Malaysian Society of Soil Science, Kuala Lumpur, Malaysia.

Stangel P J and Harris G T 1987 *In* Efficiency of nitrogen fertilizers for rice. Eds. J R Freney, R Wetselaar, A C F Trevitt and J R Simpson. pp 1-26. International Rice Research Institute, Los Banos, Philippines.