Ammonia Toxicity in Rice: Using Soil Properties to Predict Ammonia Volatilization and the Germination of Rice in Aerobic Soil

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Introduction

Recent studies indicate that aerobic rice can suffer injury from ammonia toxicity when urea is applied at seeding (*1*, *2*). Urea application rate and soil properties can influence the buildup of ammonia in the vicinity of recently sown seed and hence effect the risk of ammonia toxicity. The objectives of this study were to:

1) Evaluate the effects of urea rate on ammonia volatilization and rice seed germination for a range of soils.
2) Establish a critical level for ammonia toxicity in germinating rice seeds.
3) Assess how variation in soil properties influences ammonia volatilization and the subsequent risk of toxicity.

Materials & Methods

Soil Collection

- 15 rice soils (8 orders from 5 countries)
- Measured 8 soil properties thought to affect ammonia volatilization (See Table 2 for included properties)

Ammonia Micro-diffusion Incubations

- Urea vs Ammonium Sulfate (AS)
- 5 N rates (0, 0.25, 0.50, 0.75, 1.0 g N kg)
- RCBD with 3 reps
- Incubated for 4 days at 30oC and 80% humidity
- Paired germination and ammonia trap incubations

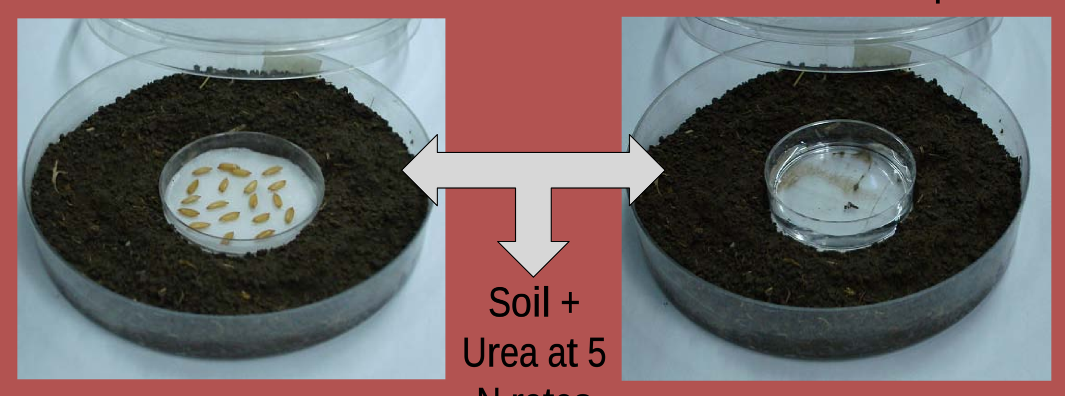

Figure 1. Illustration of ammonia micro-diffusion incubation which paired a germination trial with an ammonia trap for a given soil and N rate.

Results

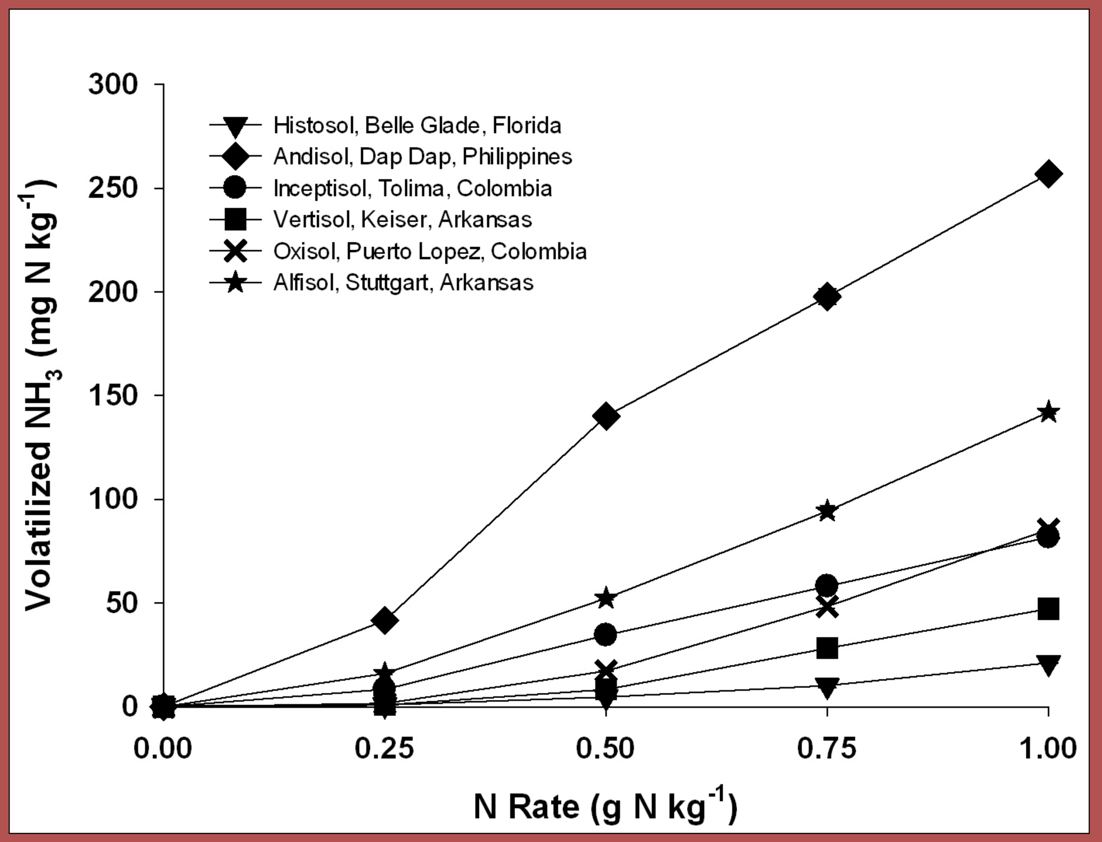

Figure 2 Effect of urea rate (g N kg^{-1} soil) on ammonia volatilization from 6 selected soils.

Table 1. Effect of urea rate (g N kg^{-1} soil) on rice germination among 6 selected soils. Values with the same letter within a column are not significantly different.

	Amount of Applied Urea (g N kg^{-1})				
	0.0	0.25	0.5	0.75	1.0
Soil Type	Germination %				
Andisol	88 a	3 d	0 e	0 d	0 c
Alfisol	92 a	82 b	68 c	5 c	0 c
Histosol	95 a	95 a	88 a	82 a	70 a
Inceptisol	88 a	73 c	30 d	0 d	0 c
Oxisol	88 a	86 b	68 c	7 c	0 c
Vertisol	88 a	85 b	77 b	38 b	8 b

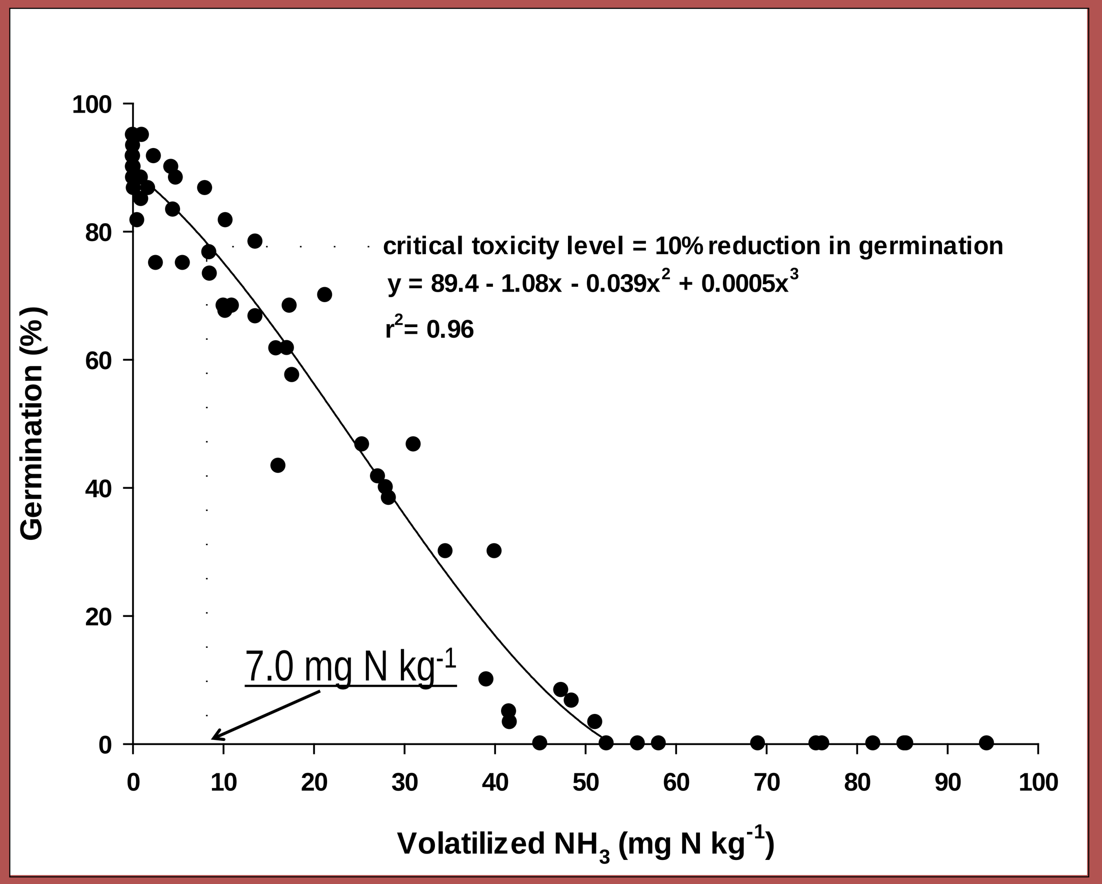

Figure 3. Effect of volatilized ammonia (mg N kg^{-1} soil) on rice seed germination (%) and estimated critical level for ammonia toxicity. Critical level equals a 10% reduction in germination relative to the y intercept.

Table 2. Eigenvalues and variance of the first three principal components and the loading values and communalities for selected soil properties.

Soil Property	PC1*	PC2	PC3	Communalities
CEC	0.98*	0.09	-0.01	0.98
BC	0.97	-0.06	-0.06	0.96
Total C	0.95	0.26	-0.10	0.97
Total N	0.95	0.22	-0.11	0.97
b	-0.75	0.61	0.08	0.93
Sand	-0.08	0.88	-0.28	0.87
Clay	-0.05	-0.90	-0.32	0.93
pH	0.30	-0.05	0.93	0.97
Eigenvalue	4.4	2.1	1.1	
PC Variance %	54.7	26.3	13.6	
Cumulative Variance %	54.7	81.0	94.6	

*Each soil property was assigned to the PC in which it had the most substantial loading. PC1, PC2 and PC3 represent the pH buffering, soil texture and initial pH components respectively.

Table 3. Results of stepwise regression for the effects of the first three principal components (pH buffering, soil texture and initial pH) on volatilized ammonia (mg N kg^{-1}) at a given N rate (0, 0.5, 1.0 g N kg^{-1}).

N Rate g N kg^{-1}	Regression Model	r^2
0.0	y = 0.09 + 0.0125*PC2 + 0.025*PC3	0.40
0.5	y = 25.46 - 5.291*PC1 + 14.084*PC2 + 10.63*PC3	0.55
1.0	y = 79.97 - 12.627*PC1 + 23.686*PC2	0.56

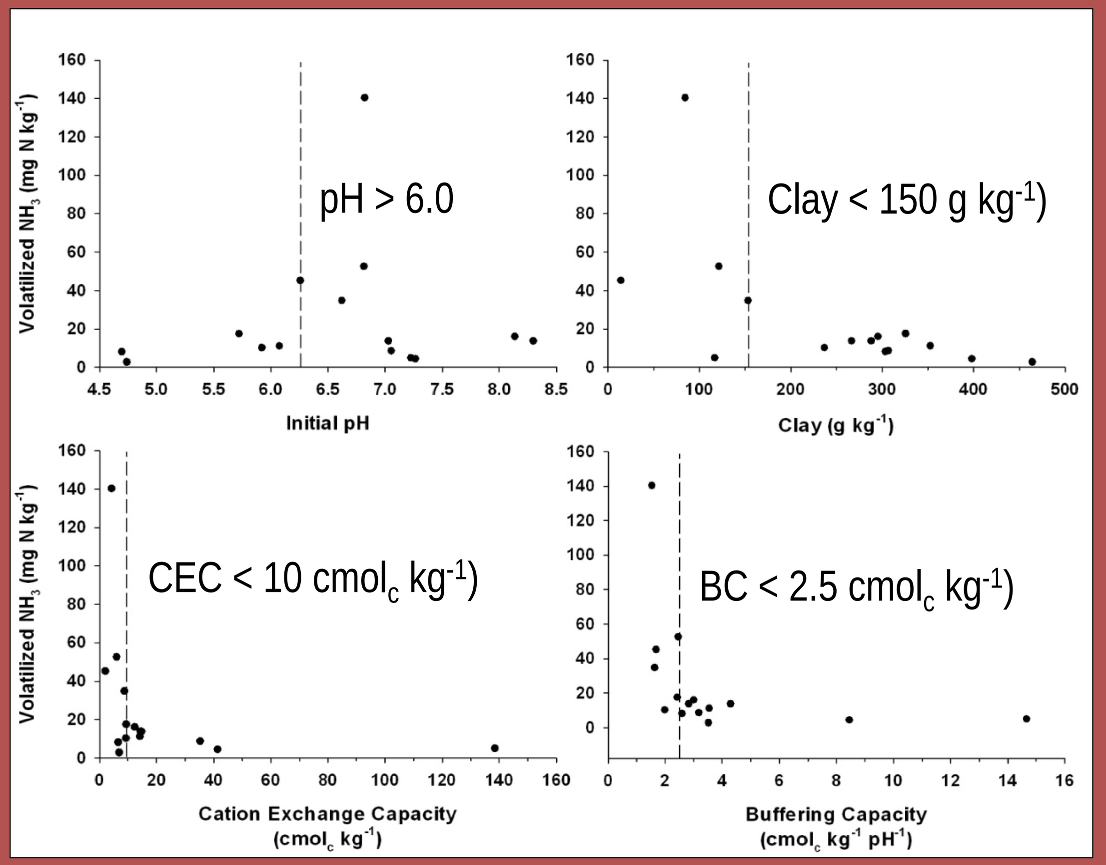

Figure 4 Ammonia volatilization risk thresholds for initial pH, clay (g kg^{-1}), CEC (cmol$_c$ kg^{-1}) and BC (cmol$_c$ kg^{-1} pH^{-1}) at the intermediate urea rate (0.5 g N kg^{-1}). Broken lines indicate risk thresholds determined by noting the point at which ammonia volatilization becomes more variable.

Conclusions

The results of this study confirm that rice is susceptible to ammonia toxicity, particularly when seeds are sown in close proximity to urea that is undergoing hydrolysis. The critical level for ammonia toxicity, whereby seed germination is reduced by 10% was found to be approximately 7 mg of ammonia-N kg^{-1}. Our findings also indicate that the total amount of ammonia released was a function of N rate, initial soil pH, soil texture and pH buffing capacity. When no N was added ammonia volatilization was low and driven mostly by properties associated with the initial pH and soil texture. The pH buffering, soil texture and initial pH components were all significant at the intermediate urea rate, while at the highest rate, ammonia volatilization was driven exclusively by soil texture and pH buffering capacity. For soils with an initial pH > 6.0 the risk of excessive volatilization increased dramatically when clay was < 150 g kg^{-1}, CEC was < 10 cmol$_c$ kg^{-1} and BC was < 2.5 cmol$_c$ kg^{-1} pH^{-1}. These findings suggest that when urea is applied to direct-seeded aerobic rice initial pH, soil texture, CEC and pH buffering capacity should all be used to assess the site-specific risks of ammonia toxicity.

Acknowledgements

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