Title

Ammonia Volatilization from Urea Incorporation with wheat and Maize Straw on a Loamy Soil in China

Authors
Dong, Wenxu
Hu, Chunsheng
Zhang, Yuming
et al.

Publication Date
2009-07-21

Peer reviewed

INTRODUCTION

Because of its high N concentration, low cost and ease of handling urea is the major nitrogen (N) fertilizer used world-wide. However, it is prone to losses by ammonia volatilization when surface applied. Incorporation of straw and other crop residues provides an energy source for microbial N and C transformations in agricultural soils, and has a significant effect on plant nutrient source-sink relationships (Per and Erik. 2001). At present little is known about the dynamics of ammonia volatilization immediately after the incorporation of urea with crop residues and fertilizer.

The North China Plain is one of the main areas of intensive cereal production in China, where the typical cropping sequence comprises winter-wheat and summer-maize. In recent years, crop residue burning has been widely replaced by straw incorporation at a rate of 12-14 t ha^{-1} equivalent to 4.8-5.6 t C ha^{-1} (Zeng et al., 2002). Such amounts of recycled straw may lead to significant changes in the physical, chemical, and biological properties of a soil's plow layer and to changes in N mobilization and losses (Campbell et al., 1996; Nyakatawa et al., 2001). These changes can have a significant impact on nutrient availability for plants.

The objective of this study was to determine the short-term effects of incorporation of residues of wheat (*Triticum eastivum* L.) or corn (*Zea mays* L.) at different soil moisture levels on 1) soil N mineralization and immobilization, 2) N loss from urea by ammonia volatilization, and 3)soil pH.

MATERIALS AND METHODS

A field experiment was conducted in the North China Plain on a loamy soil which is part of the Luancheng Station of the Chinese Academy of Sciences (37°53′N, 114°41′E, and elevation 50 m). A bulk sample was collected from the surface plough layer (0-15cm), air dried and ground to pass a 2 mm sieve. Some chemical properties of the soil sample are: pH=8.30 (1:2.5 soil:water suspension), organic matter concentration of 14.5 g kg^{-1}, total N concentration of 7.95 g kg^{-1}, available Olsen P of 15.4 mg kg^{-1} and available K of 179 mg kg^{-1}.

Treatments applied in a 2×3 factorial design comprised two levels of initial soil moisture (15% and 25%); three soil amendment (Wheat straw + Urea, Corn straw + Urea, Urea only; Table 1). Urea treatments consisted of 100 kg N ha^{-1} and straw amendments of 12 t straw $ha^{-1}$of wheat or corn. Prior to application urea and straw were grounds to a fine powder, mixing thoroughly with surface soil (0-10cm) by farm tool. And then, water was sprayed onto the soil surface.

Table 1. Treatment list of a pot experiment to examine the effects of soil moisture, urea and mixtures of urea with two straw types on ammonia volatilization on the North China Plain.

	Urea	Wheat straw + Urea	Corn straw+ Urea
Low moisture (15%)	UL	WL	CL
High moisture (25%)	UH	WH	CH

The sponge-tripping and KCl-extraction method described by Wang et al (2004) was used to measure NH_3 volatilization. Since this methodology uses a static trap for NH_3, volatilization is expected to be lower than if determined with a dynamic-chamber system in which NH_3 is continuously swept by an air steam. Therefore, this method is conservative in estimating potential NH_3 volatilization (Shahadeh et al., 1992). It should be emphasized, however, that the objective of this study was to assess the relative NH_3 volatilization potential from urea application with or without incorporated straw and we did not aim at estimating absolute flux rates from the experimental field.

During the measurement period NH_4-N and NO_3-N concentrations in the surface soil, soil pH, and soil moisture were monitored. Every day the even soil samples of 10 g dry weight were collected, extracted with 50 ml 1 M KCl after shaking for 1 h. Extracts were analyzed colorimetrically using a continuous-flow analyzer (OI, USA). Data were subjected to statistical analysis using SPSS 11.0.

RESULTS AND DISCUSSION

Ammonia volatilization rate

Addition of wheat and corn straw changed the time of maximum NH_3 volatilization and reduced the maximum daily NH_3 flux rate from urea-treated soil. Without straw, NH_3 losses peaked on day 3 after urea application and maximum rates of NH_3 emission were 4.5 and 4.0 mg N d^{-1} for the UL and UH treatments, respectively. Addition of wheat and corn straw significantly reduced maximum NH_3 emissions to about 23 to 58% of those from urea only treatments. Addition of wheat or corn straw shifted the peak of NH_3 losses 1 day ahead compared to the urea only treatment. After 3 days of incubation, the rate of volatilization dropped gradually and became statistically similar for most treatments after seven days.

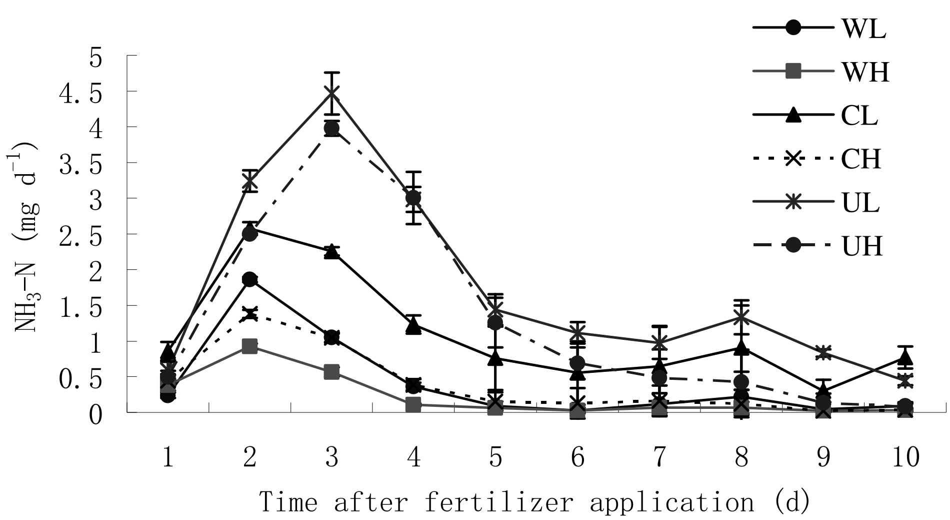

Figure 1 Rate of ammonia volatilization after urea application and amended with different types of straw. For treatment description, see Table 1

Dynamics of soil Nmin after fertilization

Two peaks of NH_4 were observed of which the first one occurred on day 2 or 3 after urea application (Figure 2). This peak was similar in all treatments. For the WL treatment NH_4-N concentration was highest at 15% soil moisture while in the CL treatment the peak was highest at 25% moisture. This indicated that the urea hydrolysis was faster with straw addition due to increased urease activity (Khind et al., 1993). The second peak occurred between day 7 and 9 in all six treatments reflecting mineralization after a rainfall event.

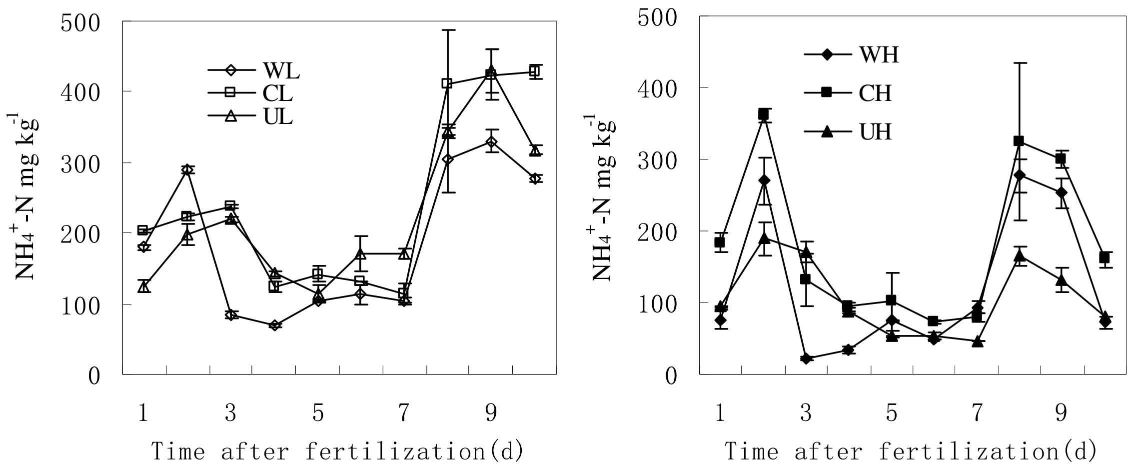

Figure 2. NH_4-N dynamics in the surface soil (0-10cm) after urea application and amended with different types of straw. For treatment description, see Table 1.

During the incubation period the soil NO_3-N concentration increased for all treatments. It was higher in UH treatments than for UL indicating the important role of moisture in nitrification. Regardless of the initial soil water content, wheat straw remarkably reduced the NO_3-N concentration. At 25% initial moisture, the NO_3-N concentration in treatments amended with corn straw (CH) was lower than in treatment without straw between day 5 and 10. At 15% initial moisture, NO_3-N in CL was similar than in UL. Our study confirms results of previous work showing that crop residue addition leads to intensive N-immobilization and therefore lower available soil NO_3–N (McKenney et al., 1995; Shindo et al., 2005).

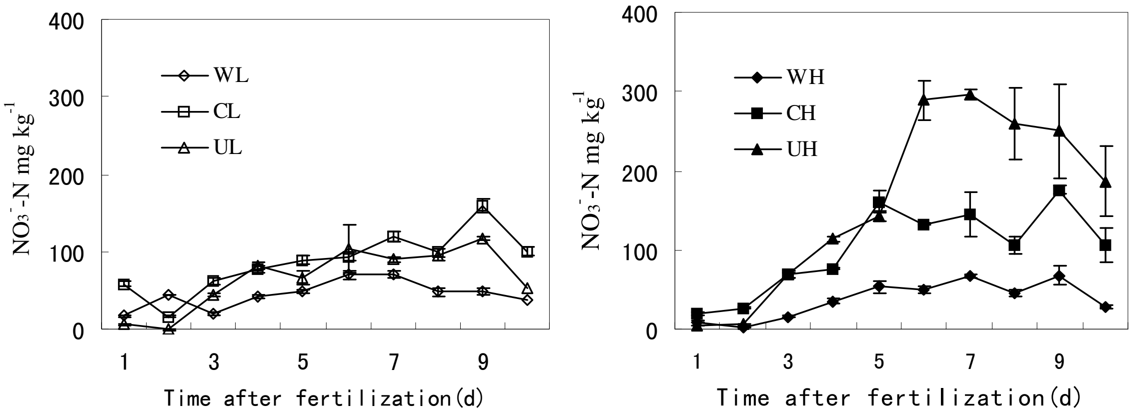

Figure 3. NO_3-N dynamics in the surface soil (0-10cm) after urea application and amended with different types of straw. For treatment description, see Table 1

Nmin recovery and cumulative NH_3-N losses

The application of straw significantly reduced the amount of Nmin recovered from the soil. This was probably due to immobilization by microorganisms decomposing the straw (Alexander, 1997). In addition, there was a trend towards lower overall recoveries with wheat straw compared to corn straw, which may have been due to better conditions for immobilization (that is undecomposed residues with high C/N ratio or low soil C/N ratios).

Table 2. Nmin recovered and cumulative ammonia-N volatilized from a loamy of the North China Plain at day 10 after incubation.

	Nmin recovered□ Moisture level		Cumulative NH_3-N volatilized Moisture level	
	15%	25%	15%	25%
	% of applied N			
Wheat straw	41.6	14.4	2.3	1.3
Corn straw	87.3	43.8	6.1	2.2
Urea only	98.4	64.9	9.9	7.4
LSD 0.05§	27.1		1.2	
Straw	** (p=0.000)		**(p=0.000)	
Moisture	**(p=0.000)		**(p=0.000)	
Straw × Moisture	NS(p=0.340)		*(p=0.016)	

*,** =significant at the 0.05 and 0.01 probability levels, respectively

§=LSD value for pairwise comparisons between any two means

□= sum of NH_4-N and NO_3-N measured in soils, and NH_3-N volatilized.

Cumulative NH_3 volatilization during the 10 day measurement period ranged from 1.3 - 9.9% of applied urea. At both moisture levels, NH_3 losses were smallest with added wheat straw and largest with urea only. Statistical analyses indicated that both straw types and soil moisture, alone and in combination, significantly affected NH_3 losses (Table 2).

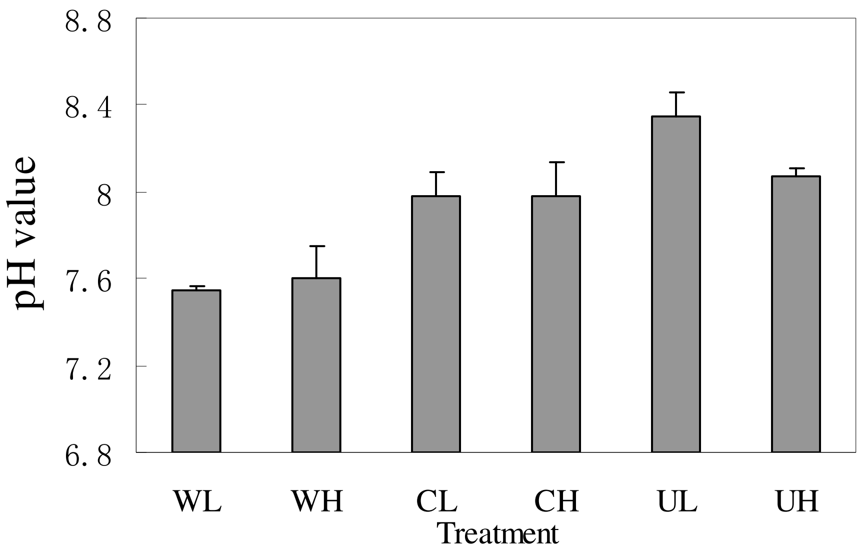

Figure 4. Soil pH in surface soil of a loamy from the North China Plain after application of urea mixed with two straw types. For treatment description, see Table 1

The driving force for NH_3 losses is the equilibrium between NH_4^+ and NH3 in the soil solution, which increases with pH and may have a significant effect on NH_3 volatilization above pH 7 (Fenn and Hossener, 1985). In this study, surface soil pH (measured on day 5) decreased after applying the urea-straw mixtures (Figure 4), while the application of urea alone led to pH values similar to the initial ones. The amount of NH_3 losses was correlated with soil pH ($r^2 = 0.73$, $P < 0.05$). The decrease in soil pH observed after the application of urea-straw mixtures might have been due to a release of protons associated with organic anions from straw, nitrification or an increased cation exchange capacity and corresponding increase in exchangeable acidity (Bolan et al., 1991; Helyar and Porter, 1989). Although soil NH_4-N concentrations in WL and CH treatments were higher than those in UL or UH treatments, daily NH_3 losses were lower on day 2 after treatment application.

CONCLUSIONS

Amendments of wheat and corn straw increased the rate of urea hydrolysis in the loamy soil of our study, which made the peak of NH_3-N losses appear 1 day earlier and lowered the peak emission compared to urea alone. Application of urea alone caused cumulative NH_3-N losses to be 7.2 - 9.7% of the urea applied. When urea was application with wheat or corn straw, cumulative NH_3-N losses were reduce to 1.1-2.1% and 2.2-7.2% of urea applied, respectively. This may because the addition of cereal straw not only led to a reduction of soil pH, but also to lower soil Nmin values, especially in higher soil moister.

ACKNOWLEDGEMENTS

This work was supported in part by the National Science and Technology Support Programme of China (2006BAD15B07) and the Chinese Academy of Sciences (Grants KSCXZ-YW-N-037). We thank Luancheng Agro-Ecosystem Experimental Station, CAS for tireless efforts with providing the experiments facility.

REFERENCES

Alexander, M. 1997. Introduction to soil microbiology. Second Edition. John Wiley and Sons, New York, NY. 467pp.

Bolan, N. S., Hedley, M. J. and White, R. E. 1991. Processes of soil acidification during nitrogen cycling with emphasis on legume based pastures. Plant Soil 134, 53--63.

Campbell, C.A., McConkey, B.G., Zentner, R. et al. 1996. Tillage and crop rotation effects on soil organic C and N in a coarse-textured Typic Haploboroll in southwestern Saskatchewan. Soil Till. Res. 37, 3-14.

Fenn, L. N. and Hossner, L. R. 1985. Ammonia volatilization from ammonium or ammonium forming nitrogen fertilizers. Adv. Soil Sci. 10: 123--169

Helyar, K. R. and Porter, W. M. 1989. Soil acidification, its measurement and the processes involved. In Robson A.D. (ed.). Soil Acidity and Plant Growth. Academic Press Australia, Sydney. pp 61--101.

Khind, C. S. and Bajwa, M. S. 1993. Urea hydrolysis in wetland soil amended with Sesbania aculeata green manure and rice straw. Biology and Fertility of Soils. 15(1): 65--67

McKenney, D.J., S.W. Wang, C.F. Drury, and W.I. Findlay. 1995. Denitrification, Immobilization, and Mineralization in Nitrate Limited and Nonlimited Residue-Amended Soil. Soil Sci Soc Am J 59:118-124.

Nyakatawa, E. Z. Reddy K. C., Sistani K. R. 2001 Tillage, cover cropping, and poultry litter effects on selected soil chemical properties. Soil & Tillage Research. 58: 69--79

Per Ambus and Erik. S.J. 2001. Crop residue management strategies to reduce N losses-interaction with crop N supply. Communications in Soil Science and Plant Analysis. 32(7/8): 981--996.

Shahadeh, H, Cabrera, M. L. and Sumner, M. E. 1992. Ammonia volatilization from urea, ammonium fulfate and nutrasweet sludge in bare and straw covered soils. Communications in Soil Science and Plant Analysis. 23(7/8): 775--786

Shindo, H., and T. Nishio. 2005. Immobilization and remineralization of N following addition of wheat straw into soil: determination of gross N transformation rates by ^{15}N-ammonium isotope dilution technique. Soil Biology and Biochemistry 37:425-432.

Wang, Z. H., Liu, X. J., Ju, X. T., Zhang, F. S. and Malhi, S. S. 2004. Ammonia volatilization loss from surface-broadcast urea: comparison of vented- and closed-chamber methods and loss in winter wheat-summer maize rotation in North China Plain. Communications in Soil

Science and Plant Analysis. 35(19/20): 2917--2939.
Zeng M.X, Wang R.F etal. 2002. Summary of returning straw into field of main agriculture areas in China. Chinese Journal of Soil Science (in Chinese). 33: 5, 336-339