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

Permalink
https://escholarship.org/uc/item/8db6h5cr

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 (\textit{Triticum aestivum} L.) or corn (\textit{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>
<thead>
<tr>
<th>Treatment</th>
<th>Urea</th>
<th>Wheat straw + Urea</th>
<th>Corn straw+ Urea</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low moisture (15%)</td>
<td>UL</td>
<td>WL</td>
<td>CL</td>
</tr>
<tr>
<td>High moisture (25%)</td>
<td>UH</td>
<td>WH</td>
<td>CH</td>
</tr>
</tbody>
</table>
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.

![Graph showing ammonia volatilization rate](image)

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](image_url)

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.

<table>
<thead>
<tr>
<th></th>
<th>Nmin recovered</th>
<th>Cumulative NH$_3$-N volatilized</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Moisture level</td>
<td>Moisture level</td>
</tr>
<tr>
<td></td>
<td>15%</td>
<td>25%</td>
</tr>
<tr>
<td>Wheat straw</td>
<td>41.6%</td>
<td>14.4%</td>
</tr>
<tr>
<td>Corn straw</td>
<td>87.3%</td>
<td>43.8%</td>
</tr>
<tr>
<td>Urea only</td>
<td>98.4%</td>
<td>64.9%</td>
</tr>
</tbody>
</table>

LSD 0.05$^\S$ 27.1 1.2

<table>
<thead>
<tr>
<th></th>
<th>% of applied N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Straw</td>
<td>**(p=0.000)</td>
</tr>
<tr>
<td>Moisture</td>
<td>**(p=0.000)</td>
</tr>
<tr>
<td>Straw x Moisture</td>
<td>NS(p=0.340)</td>
</tr>
</tbody>
</table>

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

$^\S=$LSD value for pairwise comparisons between any two means

$\S=$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).

![Graph showing pH values for different treatments](image)

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 NH$_3$ 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 moist.

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

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
Science and Plant Analysis. 35(19/20): 2917--2939.