Effect of Mixed Urease Inhibitors on N Losses From Surface-applied Urea

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Abstract

The effect of mixed urease inhibitors on NH3 volatilization from surface-applied urea was studied. The results showed that mixed urease inhibitors could effectively reduce NH3 volatilization. Mixed urease inhibitors of 0.05% N-(n-butyl)thiophosphoric triamide (NBPT) and 0.05% N-(n-propyl) thiophosphoric triamide (NPPT) reduced NH3 volatilization of 23.8% or 28.8% compared with the treatments with single NBPT or NPPT. Mixed inhibitors showed more effectiveness on slowing urea hydrolysis and maintaining lower soil NH4+ concentration for a long time than single inhibitor.

Keywords
Ammonia Volatilization; Mixed Urease Inhibitors; NBPT; NPPT

Introduction

Urea is the most widely-used and economical nitrogen fertilizer in the world due to its high content of N, ease of handling and storing and relatively low manufacturing cost (Grant and Bailey 1999). However, the utilization rate of urea is as low as 30~50% when it is applied to the surface of soil. The use of urease inhibitor has been the most useful strategy to reduce NH3 volatilization in urea-fertilized soil. Urease inhibitor could abate N losses effectively by inhibiting urease activity and slow down the hydrolysis of urea and thereby avoiding nitrate leaching and reducing gaseous N emissions (Abalos et al. 2012; Dharani et al. 2009; Francisco et al. 2011; Saioa et al. 2011; Zaman et al. 2008).

Various kinds of urease inhibitors have been identified and tested. N-(n-butyl)thiophosphoric triamide (NBPT) was one of the most effective compound of urease inhibitors and has been most widely used so far (Antisari et al. 1996; Cantarella et al. 2008; Henning et al. 2013; Xiang et al. 2008). NBPT inhibits urease after it is converted to N-(n-butyl) phosphorodiamidate (NBPTO) in soil (McCarty et al. 1989; Creason et al. 1990). However, fast urea hydrolysis was reported to occur within hours after urea was applied to soil by catalyzed of soil urease (Dawar et al. 2011). Before NBPT is converted to NBPTO, it could hardly abate urea hydrolysis. In order to solve this problem, a few researches combined phenylphosphorodiamidate (PPD) and NBPT to slow urea hydrolysis and reduce NH3 emission (Phongpan et al. 1995). It appears that initially PPD inhibited urease actively. During this period, NBPT was converted into NBPTO and inhibited the urea hydrolysis while PPD declined. The aim of this study was to evaluate the effect of mixed urease inhibitors NBPT and N-(n-propyl) thiophosphoric triamide (NPPT) on NH3 volatilization, the soil pH and soil NH4+ concentration from urea application and surface of soil.

Materials and Methods

Characterization of The Soil Sample

The soil for this research was collected from the 0-20 cm surface layer of a silt (sandy) loam in Jiading district, Shanghai. The collected soil sample was air-dried and sieved with a 2 mm sieve. The main physico-chemical properties of the soil were shown in Table 1.

Experiment

Experiment was conducted under controlled laboratory conditions. The temperature was maintained at 25°C. The
experiment included six treatments with three replicates: 1) UR, 2) UR + 0.1% NBPT, 3) UR + 0.025% NBPT + 0.075% NPPT, 4) UR + 0.05% NBPT + 0.05% NPPT, 5) UR + 0.075% NBPT + 0.025% NPPT, 6) UR + 0.1% NPPT. The fertilizer applied to the soil at a rate of 460 mg N per kg soil. The volatilization chambers were cylindrical plastic vessels with 15 cm height and a bottom area of 154 cm$^2$. The bottle top of the chamber should be air-tight and open the lid for 10 minutes to keep soil respiration every 12 hours. The vessels were filled with 300 g air-dried soil, the thick of the soil was 7-8 cm, then adjusted the soil to 40% of the maximum water holding capacity.

**TABLE 1 CHEMICAL AND PHYSICAL PROPERTIES OF THE SOIL SAMPLES USED**

<table>
<thead>
<tr>
<th>Property</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>6.62</td>
</tr>
<tr>
<td>Total N (g Kg$^{-1}$)</td>
<td>1.40</td>
</tr>
<tr>
<td>Total P (g Kg$^{-1}$)</td>
<td>0.76</td>
</tr>
<tr>
<td>Total K (g Kg$^{-1}$)</td>
<td>20.8</td>
</tr>
<tr>
<td>Sand (g Kg$^{-1}$)</td>
<td>181</td>
</tr>
<tr>
<td>Silt (g Kg$^{-1}$)</td>
<td>593</td>
</tr>
<tr>
<td>Clay (g Kg$^{-1}$)</td>
<td>226</td>
</tr>
</tbody>
</table>

**Statistical Analysis**

The statistical software SPSS 19.0 was used. Results were analyzed by one-way ANOVA to test the effects of each treatment. The least significant difference (LSD) test at 5% level was used to analysis the statistical significance of the mean differences.

**Results and Discussion**

**NH$_3$ Volatilization**

The maximum daily NH$_3$ volatilization for the treatment without inhibitor reached 7.2% of the total N applied on 5 days after fertilizer applied(Figure 1). As urease inhibitor NBPT or NPPT was added to urea, the peaks of NH$_3$ losses was delayed until day 9 for 0.1% NBPT treatment and day 8 for 0.1% NPPT treatment. The treatments with mixed urease inhibitors showed better effect, the peaks of NH$_3$ volatilization were 1.8, 1.7 and 1.9% of the total N applied on day 9, 8 and 8, respectively. These were correspond to 25.0, 29.2 and 20.8% reduction in NH$_3$ volatilization compared with the treatments with single inhibitor NBPT.

The total amounts of NH$_3$ volatilization at the end of the incubation period was 32.7% of the applied N for urea without inhibitor, while there were 14.3% and 15.3% of cumulative NH$_3$ volatilization for treatments with 0.1% NBPT and 0.1% NPPT respectively (Figure 2), which correspond to 56.3% and 53.2% reduction compared with the treatment with urea alone. The treatments with mixed urease inhibitors significant reduction NH$_3$ emission compared with the treatment without any inhibitor, the values were 11.8, 10.9 and 11.6% of the total N applied for treatments UR + 0.025% NBPT + 0.075% NPPT, UR + 0.05% NBPT + 0.05% NPPT, and UR + 0.075% NBPT + 0.025% NPPT, which correspond to 63.9, 66.7 and 64.5% reduction compared with treatment with urea alone. The cumulative NH$_3$ volatilization for treatments with mixed urease inhibitors were also lower than the treatments with single inhibitor. The treatment with 0.05% NBPT + 0.05% NPPT corresponds to 28.8% reduction compared with the treatment with 0.1% NPPT.

For the treatment with urea alone, relative high NH$_3$ volatilization occurred during 14 days after fertilizer applied, due to the excessive accumulation of soil NH$_4^+$. A number of researches had also reported that the majority of NH$_3$ losses occurred during the first few days after fertilizer application (Asing et al. 2008; Zaman and Blennerhassett 2010; Singh et al. 2008). Although NBPT could significantly reduce NH$_3$ emission, it could not be effective immediately after application. NBPT must be converted into NBPTO for inhibiting urease activity, and this process always took 1-2 days while urea was hydrolyzed rapidly during this time (Manunza et al. 1999). NPPT and NBPT have similar molecular structure and inhibitory mechanism by strongly block three urease active sites to inhibit
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urease activity (Manunza et al. 1999). Mixed urease inhibitors of NPPT and NBPT indicate reduction of NH$_3$ volatilization compared with single inhibitor.

![FIGURE 1. DAILY LOSSES OF NH$_3$ AFTER SURFACE APPLICATION OF UREA WITH SINGLE OR MIXED UREASE INHIBITORS](image1)

![FIGURE 2. TOTAL VOLATILIZATION OF AMMONIA AFTER SURFACE APPLICATION OF UREA WITH SINGLE OR MIXED UREASE INHIBITORS. VERTICAL BARS INDICATE LSD VALUES AT P=0.05](image2)

**Soil PH**

The surface layer (0-2cm) soil pH declined all the incubation period for the treatment with urea alone (Figure 3). The treatments with mixed urease inhibitors also declined at a slower rate than the control treatment after an initial rise. There were no significant differences (P=0.05) among the mixed urease inhibitors and the treatment with 0.1% NBPT. The high soil pH in the treatment with urea alone indicates fast urea hydrolysis, the significant declined after a few days fertilizer application indicated that a amount of N losses as NH$_3$ volatilization. The treatments with mixed urease inhibitors could effectively inhibit urease activity, slow urea hydrolysis and reduce the range of soil pH change compared with the treatment with single inhibitor.

**The Soil NH$_4^+$-N**

The soil NH$_4^+$ concentration of the treatment without inhibitor was higher than other treatments after fertilizer applied(Figure 4). As urease inhibitors were applied, the contents of soil NH$_4^+$ in the soil were significantly decreased, but there were no significant differences (P=0.05) among the treatments with different inhibitors. Compared with the treatment with urea alone, 0.1% NBPT has a slight increase on day 5 and then began to decline. It was indicated that urease inhibitor could effectively slow urea hydrolysis and reduce the accumulation of soil NH$_4^+$. Consequently, the urease inhibitor could extend the validity of the fertilizer for crops and increase the utilization rate. On day 11 after fertilizer applied, the content of soil NH$_4^+$ for the treatment with 0.1% NPPT was reached highest concentration of 189.9 mg N kg$^{-1}$, which corresponds to 51.7% reduction compared with the treatment without any inhibitor.

The content of soil NH$_4^+$ for the treatments with mixed urease inhibitors were no significant differences (P=0.05) compared with the treatments with single inhibitor. However, mixed urease inhibitors delayed 4 days to reach the maximum of soil NH$_4^+$ concentration compared with the treatment with 0.1% NBPT alone. It was indicated that mixed urease inhibitors have more potential to extend of validity date than single inhibitor.

**Conclusion**

Combination of two kinds of urease inhibitors NBPT and NPPT was more effective to minimize NH$_3$ volatilization than single inhibitor. Mixed urease inhibitors of NBPT and NPPT could reduce the range of soil pH change and maintain the soil NH$_4^+$ concentration on a stable level during the period compared with treatments with single inhibitor or without inhibitor. It is suggested that mixed urease inhibitors were more potential than single inhibitor on delaying urea hydrolysis and reducing N losses.
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REFERENCES


