

ABSTRACT

Urease inhibitors continued to be introduced in the agricultural market, and thus new studies with these products are warranted. **The objective of this project was to examine the utility of these inhibitors for reducing ammonia (NH₃) losses from soil (Pacolet fine sandy loam (clayey, kaolinitic, thermic, Typic Hapludults) to which cotton (*Gossypium hirsutum* L.) had been cropped.** For this laboratory experiment intact (15-cm diam., 4-cm deep) cores were removed from selected plots of the Old Rotation, with cover residue treatments of either none (continuous cotton since 1896) or winter cover (since 1896, winter cover of either hairy vetch (*Vicia villosa* Roth) or crimson clover (*Trifolium incarnatum* L.). A second set of experiments used cores from long-established tillage plots at the EV Smith Research Farm. Harvested cores were immediately removed to the laboratory and placed into glass jars for use in a 7 day experiment where emitted ammonia was trapped in boric acid, with levels measured daily. Specific treatments were: 1) no residue via winter cover, or, winter cover crop residue, and, 2) possible urease inhibitors, including various formulations of NBPT (N-(n-butyl) thiophosphoric triamide) and maleic-itaconic acid copolymer. Treatments were arranged as a 2 x 4 factorial of residue cover and urea with/without urease inhibitors (surface applied), with 4 replications of each. Each experiment was repeated in time. Statistical analyses revealed a residue by inhibitor interaction at almost every sampling date at the Old Rotation, but not at EV Smith. If the interaction was significant it was because NBPT reduced ammonia volatilization regardless of the presence of residue, while ammonia losses from urea-treated and urea plus maleic-itaconic acid copolymer were higher from soil containing crop residue, when compared to soil with little crop residue. Results from this laboratory study reveal that use of NBPT as a urease inhibitor may have utility in high residue cropping situations.

METHODS & MATERIALS

Two different ammonia volatilization experiments were conducted, all using a standard laboratory bench procedure for the evaluation of N loss via volatilization (Figure 1; O'Halloran, 1993). For the first experiment intact soil cores 15-cm in diameter and 4 cm deep (Pacolet fine sandy loam) were collected from the selected plots of the Old Rotation, with cover residue treatments of either none (continuous cotton since 1896) or winter cover (since 1896, winter cover of either hairy vetch (*Vicia villosa* Roth) or crimson clover (*Trifolium incarnatum* L.). For the second experiment that same sized cores were collected from a 20-year old tillage experiment located at the E.V. Smith Research Center, Tallasee, AL. The soil type was the same, and cores were selected from replicated plots that had been cropped to either continuous cotton or continuous cotton with winter cereal rye (*Secale cereale* L.) as a cover crop. In order to best obtain uniformity of soil moisture content soil cores were collected within 2 days after rainfall, with soil-water content and surface soil pH determined at the beginning and end of each experiment, for each treatment. Specific details regarding each soil can be found in Table 1.

Each experiment was a factorial arrangement of 4 nitrogen (N) + urease inhibitors and 2 surface residue states (none or residue present). There were four replications of every treatment. The N/urease inhibitor treatments were: 1) granular urea, 2) Limus 2.0®, 3) Agrotain Ultra®, and, 4) Nutrisphere® (Table 2). All fertilizers/urease inhibitors were applied at a rate of 112 kg ha⁻¹ to the surface of the harvested cores, with no additional water added after fertilizer application.

The volatilization system consisted of a series of 16 2-L glass canning jars, all attached to an air source via a 16-outlet manifold (Figure 1). These 16 jars allowed for 2 replications with each run, with two runs utilized to achieve four replications. Previous work with zero-N and reference urea controls have shown excellent data reproducibility from run to run. Each experiment consisted of 2 runs to generate 4 replications of each treatment. Both experiments were replicated in time.

Soil cores were placed in each jar, fertilizer/inhibitors added, and the jars sealed to start ammonia collection. Ammonia loss was measured for 7 consecutive days. This method collected ammonia via an ammonia trap system, following the method of O'Halloran (1993). Air flow was generated by passing 100 mL min⁻¹ air stream through a 5N sulfuric acid air scrubber and across each jar, with resultant NH₃ trapped in 100 mL of 0.01 N boric acid. The boric acid trap was changed everyday for 7 days, with collected samples titrated to the original pH of the boric acid using 0.01 N sulfuric acid. Mass and percent of volatilized NH₃ were calculated using the formulas:

mg-N = mLs acid * N acid * 14, where 14 is the equivalent weight of N and
% N volatilized = (total mg-N for each treatment/X) * 100, where X is the mg N per jar.

Table 1. Fertilizer products with urease inhibitors used in the laboratory ammonia volatilization experiments, Auburn, AL, 2017.

Product (Trade name)	Urease Inhibitor
Limus 2.0 BASF Corporation 26 Davis Drive, Research Triangle Park, NC. 27709	NBPT (N-butyl thiophosphoric triamide) & NPPT (N-propyl thiophosphoric triamide)
Agrotain Ultra Koch Agronomic Services 4111 East 37 th St N, Wichita, KS. 67220	NBPT (N-butyl thiophosphoric triamide)
Nutrisphere 1001 Winstead Drive, Suite 480, Cary NC. 27513	maleic-itaconic copolymer

Table 2. Soil characteristics for the two soils used for volatilization experiments, AL 2017.

Experiment	Treatment	Carbon	Organic Matter	Residue Cover
		mg kg ⁻¹	percent	
Old Rotation	No crop residue	4300	0.7	13
	Crop residue	11400	2	53
EVS	No crop residue	5775	0.98	16
	Crop residue	8575	1.5	93

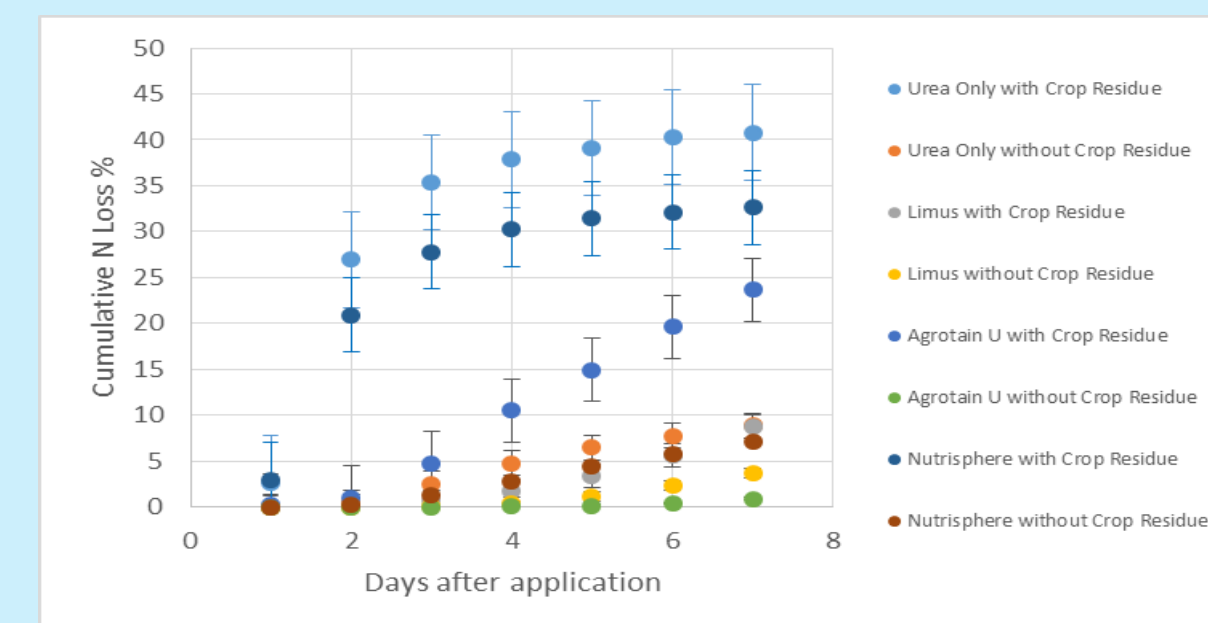


Figure 2: Cumulative N Loss as a function of urease inhibitor and residue, Run 1, Old Rotation.

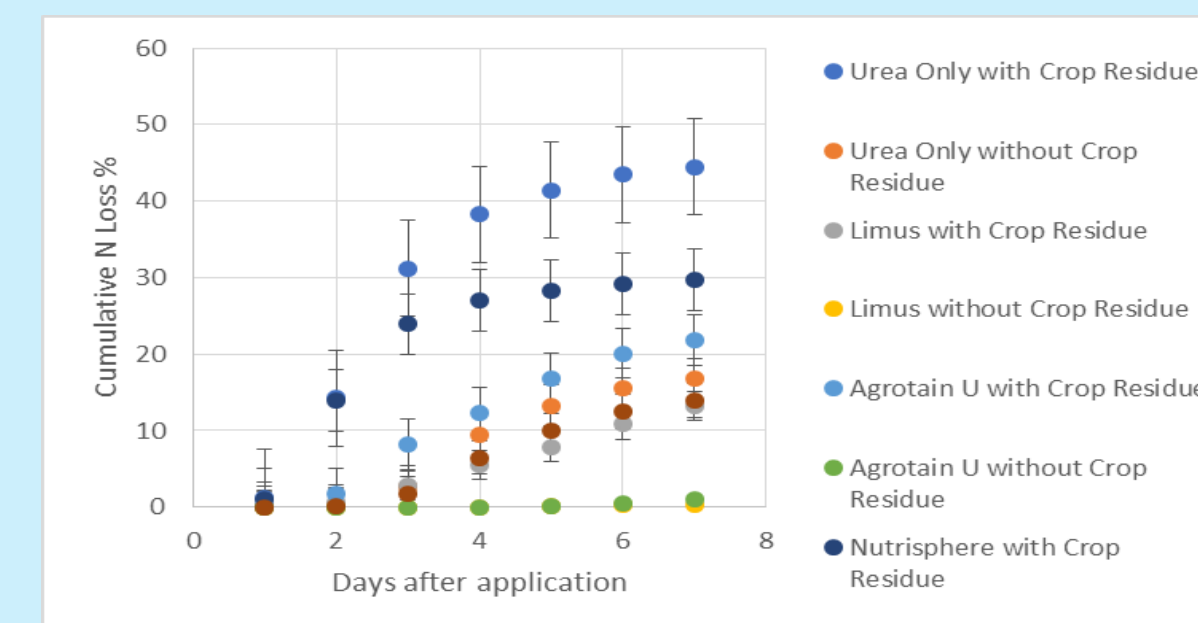


Figure 3: Cumulative N Loss as a function of urease inhibitor and residue, Run 2, Old Rotation.

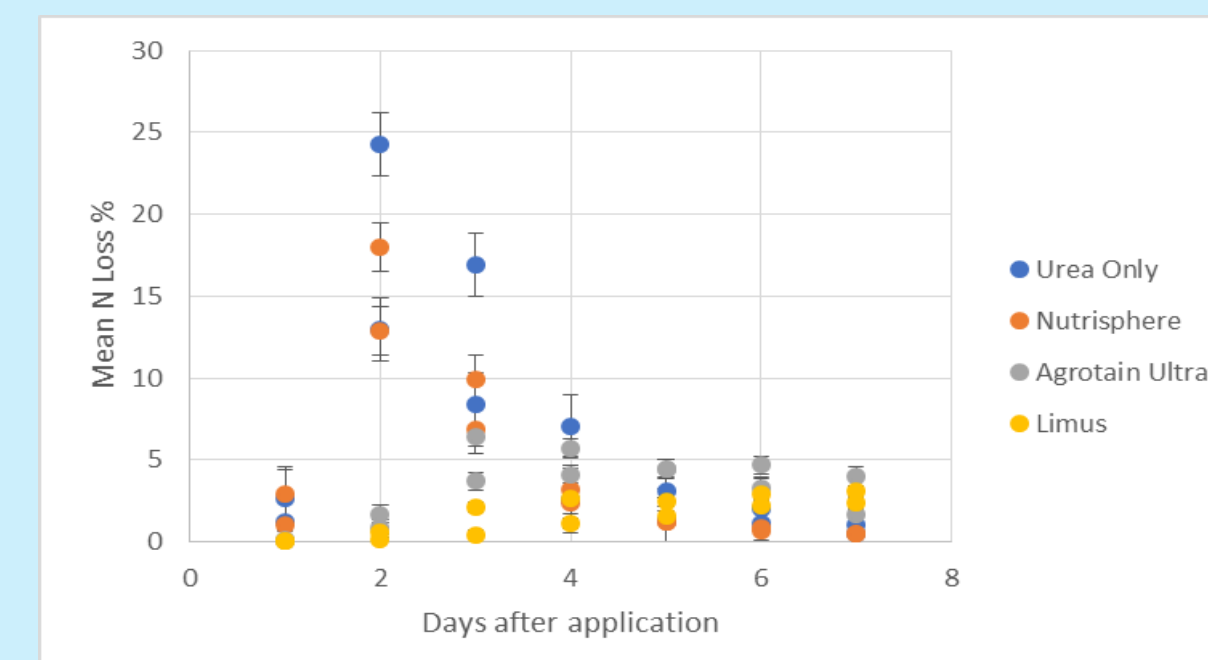


Figure 4: Mean N loss with crop residue present in both Runs 1 and 2 using soil cores from the Old Rotation experiment site.

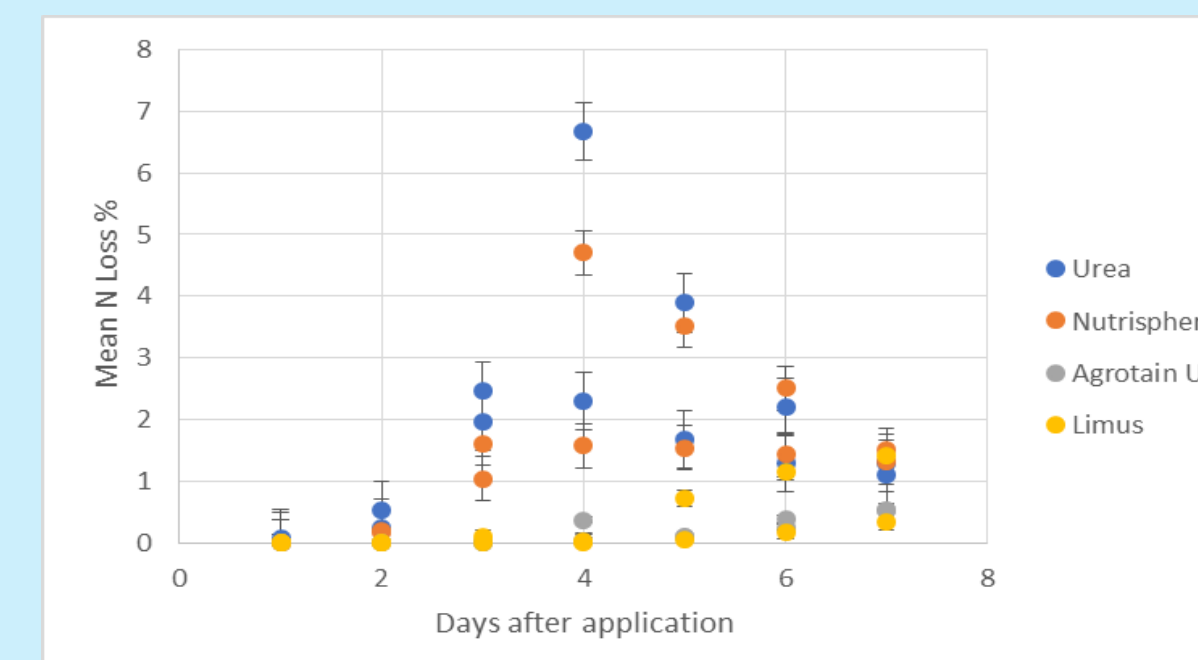


Figure 5: Mean N loss without crop residue in both Runs 1 and 2 using soil cores from the Old Rotation experiment site.

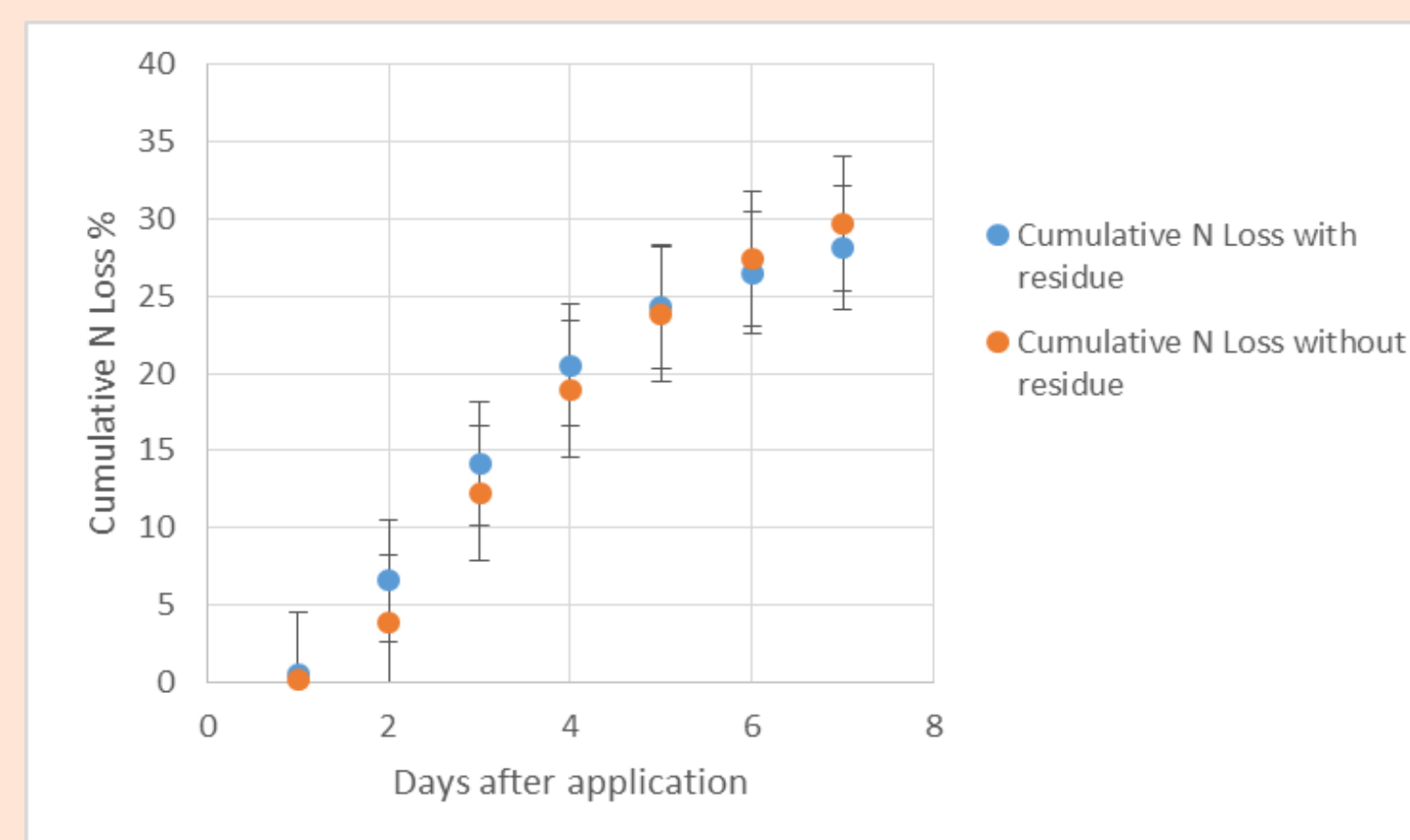


Figure 6: Cumulative N loss from volatilization as affected by presence or absence of surface crop residue, averaged over all N source/inhibitors, Run 1, E.V. Smith Research Station.

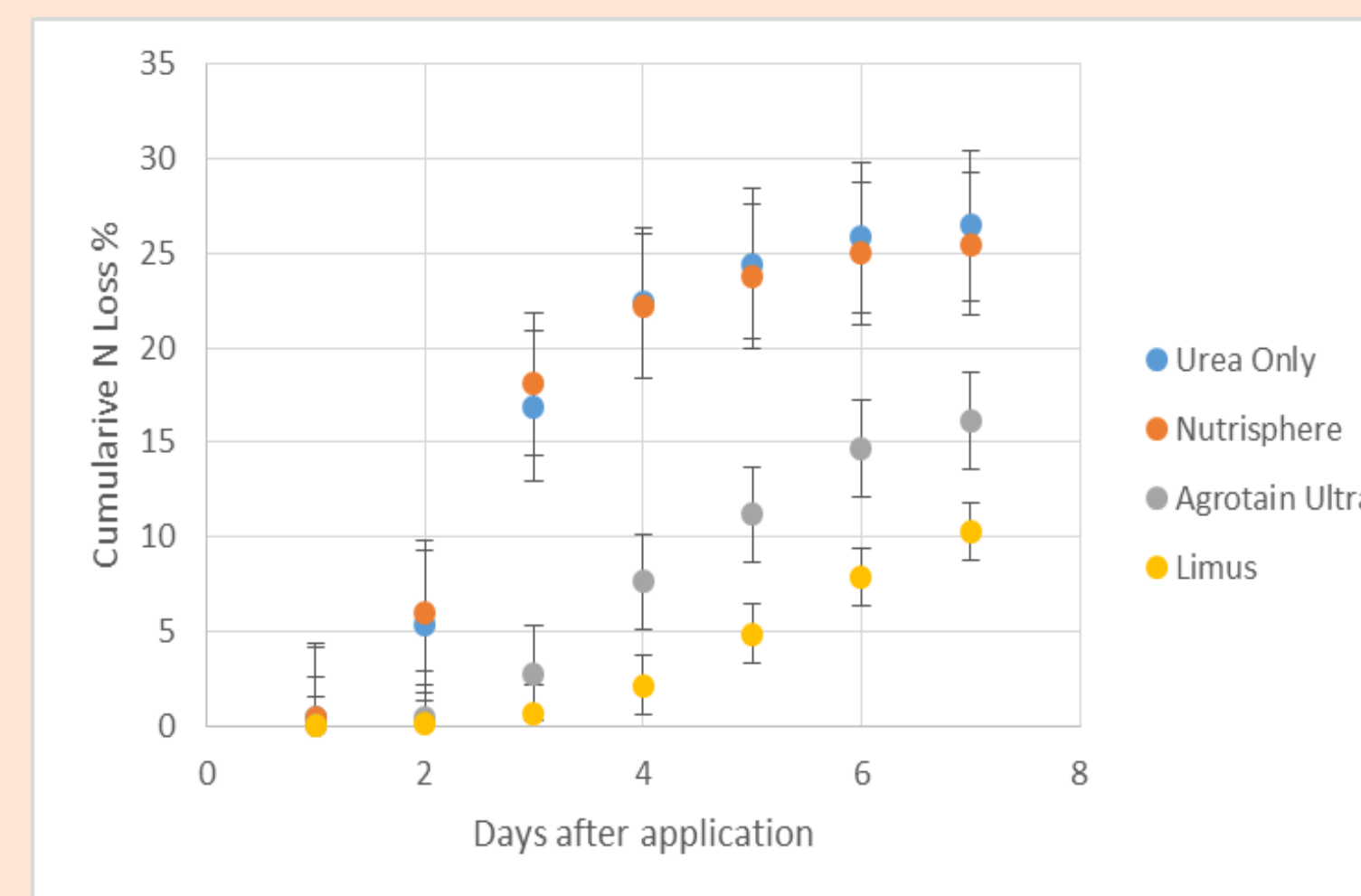


Figure 7: Cumulative N loss from volatilization as affected by N source/inhibitors, averaged over the presence or absence of surface crop residue, Run 2, E.V. Smith Research Station.

LITERATURE REVIEW

Volatilization is the one of the main pathways of loss from the Nitrogen (N) cycle. Urea fertilizers are very susceptible to volatilization due to the urease enzyme found within soils. This enzyme is produced by soil microbes associated with the decomposition of crop residue and other sources of organic matter (Pierzynski et al., 2005). It acts as a catalyst in the decomposition of urea fertilizers, therefore leading to the production of NH₄⁺ and ammonia gas (NH_{3(g)}) (Pierzynski et al., 2005). This NH_{3(g)} is no longer available for crop uptake and lost to the atmosphere. The presence of organic matter on the soil surface has shown to increase N losses due to volatilization. In a study using wheat straw mulching on the soil surface, greater N losses were observed in treatments with increasing organic matter on the soil surface (Francisco et al., 2010). This was mainly due to the increased presence of the urease enzyme.

Through the use of urease inhibitors, this hydrolysis reaction can be delayed by blocking the urease enzyme. As a result, producers may have more time to receive additional rainfall or irrigate, therefore moving urea down into the soil profile where it is not as susceptible to volatilization. One of the most commonly used urease inhibitors is N-butyl thiophosphoric triamide (NBPT). Multiple studies have shown that NBPT is successful in delaying NH_{3(g)} loss to volatilization (Frame et al., 2012; Engel et al., 2011). Another urease inhibitor commonly used, N-propyl thiophosphoric triamide (NPPT), is also effective in delaying volatilization losses. It is commonly mixed with NBPT, and this mixture has proven to reduce volatilization losses as well (Qianqian et al., 2015). The other urease inhibitor used in this study is a maleic-itaconic copolymer, shown to have little to no effect in delaying volatilization (Franzen et al., 2011) There are multiple urease inhibitors that are commercially available, but the evaluation of these various inhibitors in surface applications when crop residue is present has not been thoroughly evaluated. The objective of this project was to examine the utility of these inhibitors for reducing ammonia (NH₃) losses from soil (Pacolet fine sandy loam (clayey, kaolinitic, thermic, Typic Hapludults)) to which cotton (*Gossypium hirsutum* L.) had been cropped.

RESULTS

- For The Old Rotation site there was a significant inhibitor x residue interaction in both runs of this experiment (Figures 2 – 5). This occurred because losses of ammonia from urea fertilized plots were high, especially when residue was present (Figure 4). Application of N with Limus or Agrotain U reduced ammonia loss to a greater degree (as compared to only urea) when residue was present, as compared to when it was not (Figures 2 and 3).
- Loss of N volatilized as ammonia was lowest in treatments containing a urease inhibitor with NBPT (N-butyl thiophosphoric triamide) and/or NPPT (N-propyl thiophosphoric triamide).
- Mean N lost as ammonia was greatest in the first 4 days, with or without crop residue present, and decreased thereafter (Figures 4 and 5).
- Regardless of the presence of residue, cumulative ammonia loss occurred in the following order in both Runs of the experiment: urea ≥ Nutrisphere > Agrotain U = Limus.

- Unlike experiments conducted using soil from the Old Rotation, the interaction of residue and inhibitor was not significant, at any of the 7 sampling days, in either Run of the experiment.
- This may be a function of several factors, including initial soil moisture content and percent residue cover (Table 2).
- In Run 1, days 1 and 2 of data collection there was significantly greater ammonia loss from plots that had surface residue than from plots that did not. However, ammonia losses were small at those sampling intervals. When totaled over the 7 days there was no significant difference in ammonia loss via volatilization due to the presence or absence of surface residue (Figure 6).
- In Run 2 the presence or absence of surface residue never affected ammonia loss, with a cumulative 7 day total of 19.4% N loss (as a percent of N applied), averaged over all treatments.
- Cumulative N loss due to the presence or absence of urease inhibitors was in the order (Run1): urea = Nutrisphere > Agrotain Ultra ≥ Limus. For Run 2 the order of measured ammonia loss was: urea = Nutrisphere > Agrotain Ultra = Limus.



Figure 1. Laboratory bench procedure for determining ammonia loss from fertilized turfgrass, following the procedure of O'Halloran, 1993.

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