ASSESSMENT OF ENHANCED EFFICIENCY UREA PRODUCTS ON MAIZE IN MISSOURI

Dara Boardman, James Houx III, and Felix Fritschi
University of Missouri, Columbia, Missouri

Abstract

Urea is the most commonly used N fertilizer worldwide, but can be easily lost to the environment through ammonia volatilization. Enhanced efficiency fertilizers (EEF) have been developed to help prevent these losses. Field studies were conducted from 2009 to 2011 on a Mexico silt loam (fine, smectitic, mesic, Vertic Epiaqualf) to determine the efficacy of five EEF urea products compare to untreated urea when surface applied to no-till maize (*Zea mays* L.). Treatments included untreated urea, Agrotain, Nutrisphere, SuperU, ESN, Duration-75, UAN (used for comparison), and a zero N control. Yield varied from year to year, but products showed distinct trends with UAN and Duration-75 producing the highest yields and the urease inhibitor and nitrification inhibitor products being equal to untreated urea. To determine ammonia volatilization, a static semi-open chamber system was employed using foam sorbers soaked in 0.73 *M* H_3PO_4:33% glycerine (v:v) solution to trap ammonia. Over the course of 82 days following fertilizer application, cumulative volatilization ranged from 2.57 to 8.37% of the N applied, but volatilization of specific products varied among years, most likely as a result of differing rainfall patterns. Application of products that delayed the release of N the longest, such as Duration-75 and ESN, generally resulted in higher yields independent of ammonia volatilization.

Introduction

The most commonly used N fertilizer worldwide is urea ($CO(NH_2)_2$). The International Fertilizer Industry Association (IFA) reported that in 2009 world urea usage was more than 56 million Mg. The N fertilizers that are most commonly used after urea were nitrogen-phosphorus-potassium (NPK) compounds and ammonium phosphate (AP) with 7.5 million Mg each (IFA, 2011). Urea is commonly used because it is easily transported and applied, as well as having a high percent of N (46%). Despite this, there are drawbacks. Urea is easily hydrolyzed by urease, an enzyme found in soil that is produced by bacteria and fungi as well as released from organic matter (OM). Once urea is hydrolyzed, it can be lost from the soil through multiple pathways, such as volatilization of ammonia (NH_3) or leaching of nitrite (NO_2^-) and nitrate (NO_3^-).

Urea is affected by many environmental factors as well as cultural practices that determine the placement and means of application, including the form of N applied (Andraski and Bundy, 2008; Fox and Hoffman, 1981), the tillage practices used (Andraski and Bundy, 2008; Jones et al., 1969), how it is applied (granular, liquid, injected, banded, pre-plant, sidedress, etc.) (Bandel et al., 1984; Fowler and Brydon, 1989), and soil moisture and/or rainfall after application (Fox and Hoffman, 1981; Keller and Mengel, 1986; Meyer et al., 1960).

By comparing the yield of maize fertilized with urea and ammonium nitrate, Fowler and Brydon (1989) showed that yield differences were due to less N being available for the crop with urea as a result of denitrification or volatilization. Extensive research has been conducted on urea to determine what environmental factors contribute to the process and rate of volatilization. A broad range of volatilization levels have been reported, including some as low as 3% of the N fertilizer applied (McInnes et al., 1986), while others found up to 30% (Fowler and Brydon, 1989; Keller and Mengel, 1986) and some as high as 50% or greater (Ernst and Massey, 1960; Hargrove et al., 1977).

Due to the widespread usage of urea, researchers have focused on identifying ways to increase efficiency by reducing volatilization and/or leaching. In recent years, many fertilizer companies have developed products to increase fertilizer efficiency. The resulting fertilizers have been labeled Enhanced Efficiency Fertilizers (EEF). A number of strategies have been developed to alter the fate of fertilizer N in the soil. The approaches include polymer coatings, urease inhibitors (UI), and nitrification inhibitors (NI), with UI and NI being used together or separately. All three approaches are used with urea fertilizers in an effort to decrease urea loss through volatilization and leaching. Each of the three types of products is designed to protect urea from hydrolysis or nitrification until the plants are at a developmental stage that would enable them to use significant amounts of N. This aids in the prevention of fertilizer loss while providing N to plants when it is needed in large quantities.

Due to various environmental influences and management practices, large portions of the urea applied by a producer may be lost through volatilization or leaching. The goal of this study was to evaluate the effect of polymer coating, urease inhibitors, nitrification inhibitors or both urease and nitrification inhibitors on N volatilization from surface applied urea in no-till maize.

Materials and Methods

This experiment was conducted for three years, 2009 to 2011, at the University of Missouri Bradford Research and Extension Center, Columbia, Missouri (38 53' N; 92 12' W). The soil at the research site is classified as a Mexico silt loam (fine, smectitic, mesic, Vertic Epiaqualf) and was the previous season in no-till soybean (*Glycine max* L.). Maize (*Zea mays* L.) hybrid Pioneer 33M16 was no-till planted in 0.76-m rows to achieve 78,000 plants ha^{-1}. Nitrogen treatments were broadcast applied at a rate equivalent to 168 kg N ha^{-1} using untreated urea, Agrotain (UI)(Agrotain Int. LLC, St. Louis, MO, USA), Nutrisphere (UI and NI)(SFP, Leawood KS, USA), SuperU (UI and NI) (Agrotain Internatinoal LLC, St. Louis, MO, USA), ESN (polymer coated urea)(Agrium Inc. Denver, CO, USA), Duration-75 (polymer coated urea) (Agrium Inc. Denver, CO, USA), UAN (used for comparison), and a zero N control. Each treatment was randomly assigned to 6.1 x 29.7 m plots and replicated four times. At maturity, maize was harvested from two rows from each plot (29.7 m length) using a research combine.

Ammonia loss due to volatilization was measured using a semiopen-static system as described by Griggs et al. (2007). This system uses 0.13 x 0.75 m (dxh) clear, acrylic tubing placed into 0.15 x 0.10 m (dxh) rings (schedule 120 PVC) that were imbedded 50 mm into the soil within each plot. Nine of these rings were imbedded in each plot so that chambers could be moved to a new location at each sampling. The area within each ring had a pre-weighed quantity of fertilizer corresponding to the whole plot application applied. Polyurethane foam sorbers 25.4 mm thick were cut slightly larger than the inside diameter of the acrylic tubes in order for the sorbers to remain in place during the trapping process. To trap volatilized NH_3, sorbers were impregnated with 18 mL of a 0.73 *M* H_3PO_4:33% glycerine (v:v) solution. Each chamber contained two sorbers; one sorber was placed 150 mm from the top of the chamber to absorb NH_3 volatilized from the soil and the second sorber was placed level to the top of the chamber to avoid contamination from the atmosphere. At each sampling date, both sorbers were replaced and chambers were moved to a new ring in the plot. Ammonia from the sorbers was extracted by soaking in 100 mL 2 *M* KCl solution. A 50 mL aliquot of the 2 *M* KCl extract was frozen until analysis. Ammonia analysis was conducted with a Lachat QuickChem 8000 auto ion analyzer using QuickChem® Method 12-107-06-2-A (Lachat Instruments, Loveland, CO, USA).

Statistical Analysis

Grain yield and cumulative NH_3 losses for each product were compared by ANOVA using PROC MIXED (SAS 9.2, SAS Institute, Cary, NC, USA) specifying replication and all interactions with replication as random. Mean separation was conducted with Fisher's protected least significant difference (LSD) test at $P \leq 0.05$. Results for grain yield and ammonia losses differed between years so analyses were conducted within years.

Results and Discussion

Yield

Maize yields for the three years of the experiment were variable (Figure 1). As expected, all N fertilization treatments out-yielded the zero N control in every year. Significant differences among N treatments were observed in 2009 and 2010, but not in 2011. Maize yields in 2011 were lowest overall. Hail damage in July, as well as a moderate drought, likely caused the low yields and masked treatment differences that were observed in the previous two years. However, UAN and Duration-75 always produced the highest yields, while all inhibitor products performed comparable to untreated urea.

Ammonia Volatilization

In each year, differences in cumulative volatilization were observed among products (Table 1). The products produced different results based on timing of rainfall in relation to when the fertilizer should become available. In all three years, ESN and Duration-75 caused N release approximately 10 to 15 days after fertilization (DAF), based on increased NH_3 volatilization, whereas other products were available to the maize upon application. The biggest difference between the three years is that in 2009 and 2010 (Figures 2 and 3, respectively), there was rainfall during or soon after that release point. In 2011 (Figure 4), that was not the case; rainfall did not occur again until 35 days after fertilization, or approximately 20 days after the fertilizer was released. This is the only year of the three in which ESN and Duration-75 had significantly higher N losses than the other products. This is probably due to the mechanism these products employ to delay the release of N. Due to the polymer coating, ESN and Duration-75 are not fully incorporated into the soil like the other products. This led to more of the ESN and Duration-75 remaining on the surface of the soil and when the protective coating broke down, there was no rainfall for incorporation. Ammonia volatilization from these two products is most obvious during 2011 and during the period of no rainfall; however, loss slowed down once rainfall occurred again around 35 DAF.

Volatilization trends following treatment with inhibitor products were similar to those of polymer coated products, but the timing was different. Since the inhibitor products are available for environmental interaction upon application, the environmental effects can be noticed soon after the fertilizer is applied. Nutrisphere tended to produce the highest N losses of the inhibitor products. In both 2009 and 2010, Nutrisphere had the highest initial N loss. In 2011, the only product that had a higher initial N loss was SuperU. Both Nutrisphere and SuperU are UI and NI. For 2010 and 2011, these products had almost identical patterns of NH_3 volatilization. Agrotain tended to produce slightly less loss than Nutrisphere and SuperU in all years, although not statistically different. The inhibitors tended to decrease NH_3 volatilization compared to untreated urea with the exception of Nutrisphere in 2009. The UAN treatment used for comparison, exhibited losses that were generally average compared to the other products.

Table 1. Cumulative percent loss at 25 days after fertilization (DAF) and 82 days after fertilization of N fertilizer applied to maize.

	Treatment	Cumulative % loss (25 DAF)*	Cumulative % loss (82 DAF)*
2009	Nutrisphere	6.08 A	
	Urea	4.80 AB	
	UAN	4.10 AB	
	ESN	3.95 ABC	
	Agrotain	2.61 ABC	
	Duration-75	1.47 BC	
	Zero N	0.46 C	
2010	Urea	6.15 A	8.37 A
	Agrotain	4.49 AB	7.54 AB
	SuperU	5.51 A	7.36 AB
	Nutrisphere	5.32 A	6.89 AB
	UAN	5.06 A	6.14 AB
	Duration-75	1.99 C	5.17 BC
	ESN	2.72 BC	4.92 BC
	Zero N	1.50 C	2.74 C
2011	ESN	4.37 A	8.36 A
	Duration-75	1.75 BC	6.77 B
	Urea	2.33 B	3.57 C
	SuperU	1.65 BC	3.26 C
	Nutrisphere	1.79 BC	2.88 C
	Agrotain	1.27 CD	2.57 CD
	Zero N	.57 D	1.78 D

*Different letters indicate significant difference using Fisher’s LSD ($p<0.05$).

This data showed distinctive trends for cumulative N loss due to volatilization over the course of a field season. Cumulative losses at 25 days after fertilization were always below 7%, and at 82 days after fertilization cumulative losses were always below 9%, even for untreated urea (Table 1). In contrast, others have noted losses via NH_3 volatilization to range from 30 to 50% of the applied fertilizer N (Ernst and Massey, 1960; Fenn and Kissel, 1973; Fowler and Brydon, 1989; Keller and Mengel, 1986). However, McInnes et al. (1986) reported NH_3 volatilization losses from urea fertilizer in wheat of 7.6% of the fertilizer applied, more closely aligning with those observed in this study. Losses due to denitrification, although not measured, were thought to contribute to the lower yields in 2009 and 2010.

Conclusions

Ammonia volatilization intensity between years varied. Part of this variability can be attributed to the differences in climatic events in relation to the availability of the N. Based on the data, it can be assumed that the PCU products, ESN and Duration-75, release N from the urea around 15 DAF, causing these products to be exposed to different weather patterns than the other products. However, in two of the three years, Duration-75 and ESN produced lower NH_3 volatilization than UI/NI or untreated urea. The UI/NI treatment NH_3 volatilization levels were comparable to untreated urea each year. Timing of rainfall in relation to application or release of N appears to affect the treatments in this study but as that was not a parameter that was controlled, further research must be conducted.

Bibliography

Andraski, T.W. and L.G. Bundy. (2008) Corn Residue and Nitrogen Source Effects on Nitrogen Availability in No-Till Corn. Agron J 100:1274-1279. DOI: 10.2134/agronj2008.0039.

Bandel, V.A., F.R. Mulford, and H.J. Bauer. (1984) Influence of fertilizer source and placemnt on no-tillage corn. J. Fert. Issues:6.

Ernst, J.W. and H.F. Massey. (1960) The Effects of Several Factors on Volatilization of Ammonia Formed from Urea in the Soil. Soil Sci. Soc. Am. J. 24:87-90. DOI: 10.2136/sssaj1960.03615995002400020007x.

Fenn, L.B. and D.E. Kissel. (1973) Ammonia Volatilization from Surface Applications of Ammonium Compounds on Calcareous Soils: I. General Theory. Soil Sci. Soc. Am. J. 37:855-859. DOI: 10.2136/sssaj1973.03615995003700060020x.

Fowler, D.B. and J. Brydon. (1989) No-Till Winter Wheat Production on the Canadian Prairies: Placement of Urea and Ammonium Nitrate Fertilizers. Agron J:7.

Fox, R.H. and L.D. Hoffman. (1981) The Effect of N Fertilizer Source on Grain Yield, N Uptake, Soil pH, and Lime Requirement in No-Till Corn. Agron. J. 73:891-895. DOI: 10.2134/agronj1981.00021962007300050032x.

Griggs, B.R., R.J. Norman, W.E. Wilson, and N.A. Slaton. (2007) Ammonia Volatilization and Nitrogen Uptake for Conventional and Conservation Tilled Dry-Seeded, Delayed-Flood Rice. Soil Sci. Soc. Am. J. 71:745-751. DOI: 10.2136/sssaj2006.0180.

Hargrove, W.L., D.E. Kissel, L.B. Fenn. (1977) Field Measurements of Ammonia Volatilization from Surface Applications of Ammonium Salts to a Calcareous Soil. Agron. J. 69:473-476. DOI: 10.2134/agronj1977.00021962006900030035x.

IFA I.F.I.A. (2011) World Nitrogen Consumption.

Jones, J.N.J., J.E. Moody, and J.H. Lillard. (1969) Effects of Tillage, No Tillage, and Mulch on Soil Water adn Plant Growth. Agron J 61:3.
Keller, G.D. and D.B. Mengel. (1986) Ammonia Volatilization from Nitrogen Fertilizers Surface Applied to No-Till Corn. Soil Science Society of America Journal 50:4.
McInnes, K.J., R.B. Ferguson, D.E.Kissel, and E.T. Kanemasu. (1986) Ammonia Loss from Applications of Urea-Ammonium Nitrate Solution to Straw Residue. Soil Sci. Soc. Am. J. 50:969-974. DOI: 10.2136/sssaj1986.03615995005000040028x.
Meyer, R.D., R.A. Olson, H.F. Rhoades. (1960) Ammonia Losses from Fertilized Nebraska Soils. Agron. J. 53:241-244. DOI: 10.2134/agronj1961.00021962005300040010x.

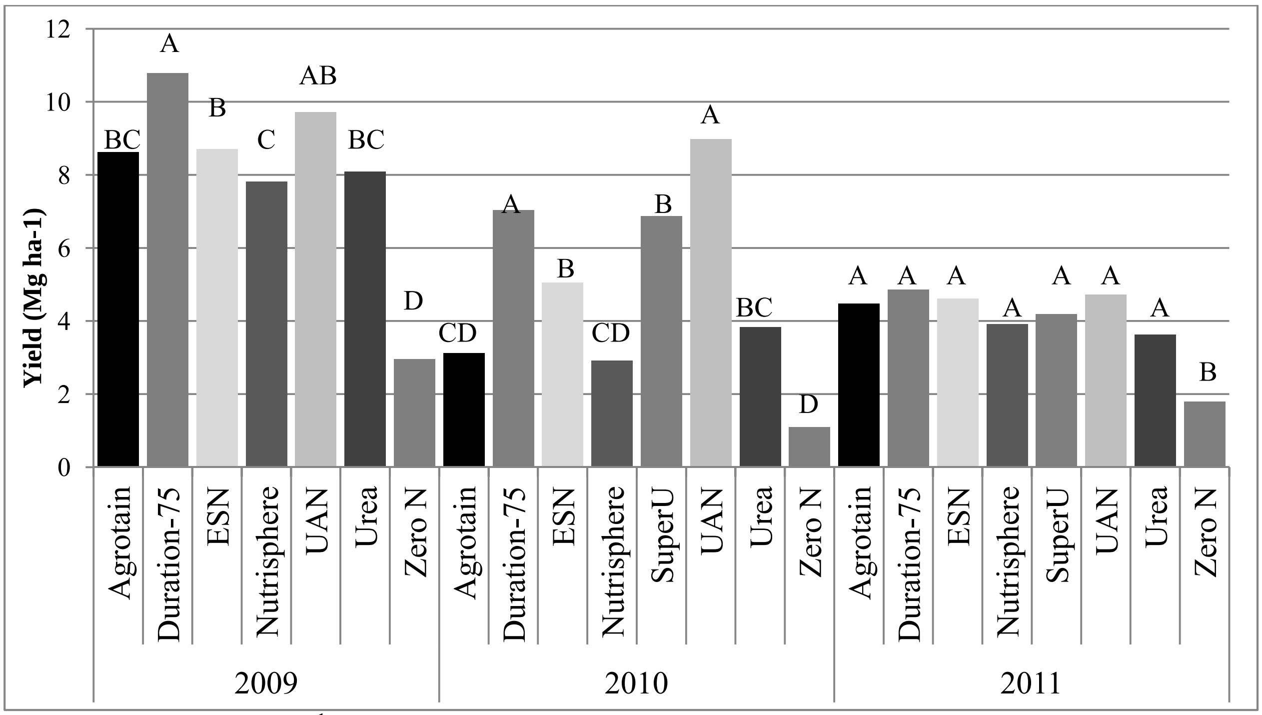

Figure 1. Yield (Mg ha^{-1}) of maize treated with EEF urea products compared to untreated urea, UAN, and Zero N treatments. Different letters indicate significant difference using Fisher's LSD ($p<0.05$)

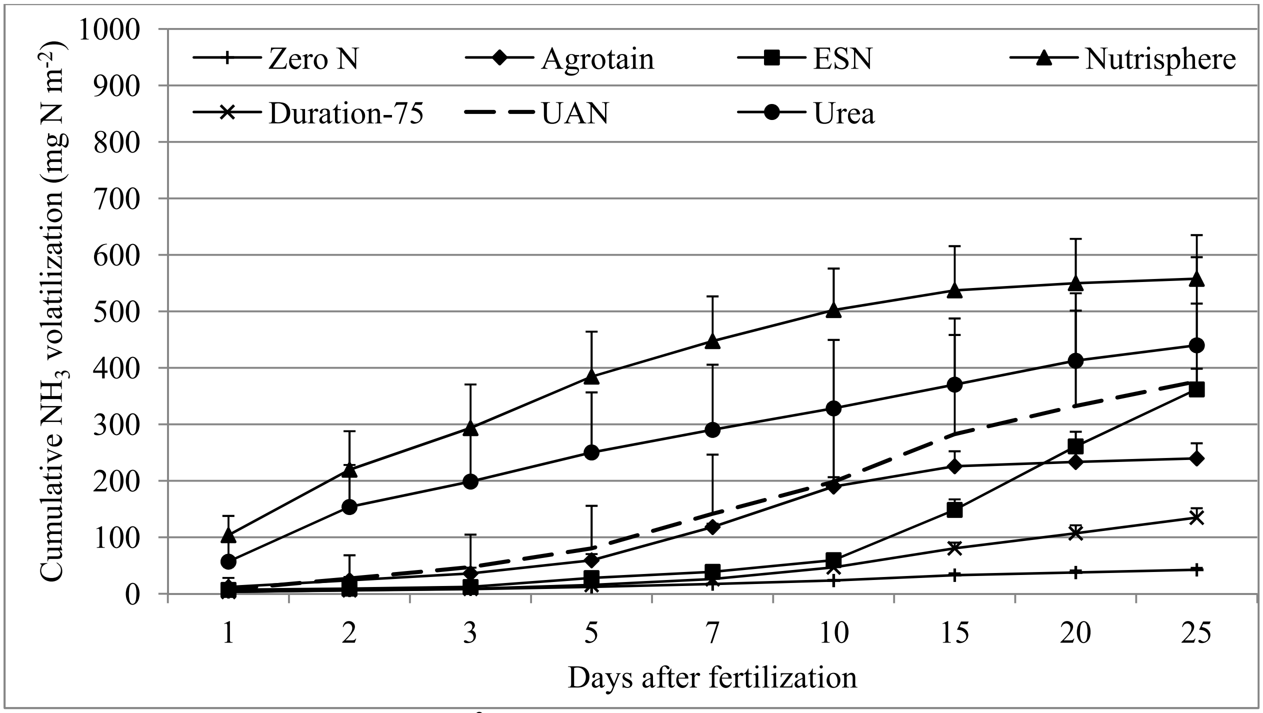

Figure 2. 2009 N loss (mg N m^{-2}) via ammonia volatilization from maize fertilized with enhanced efficiency urea products, untreated urea, or UAN.

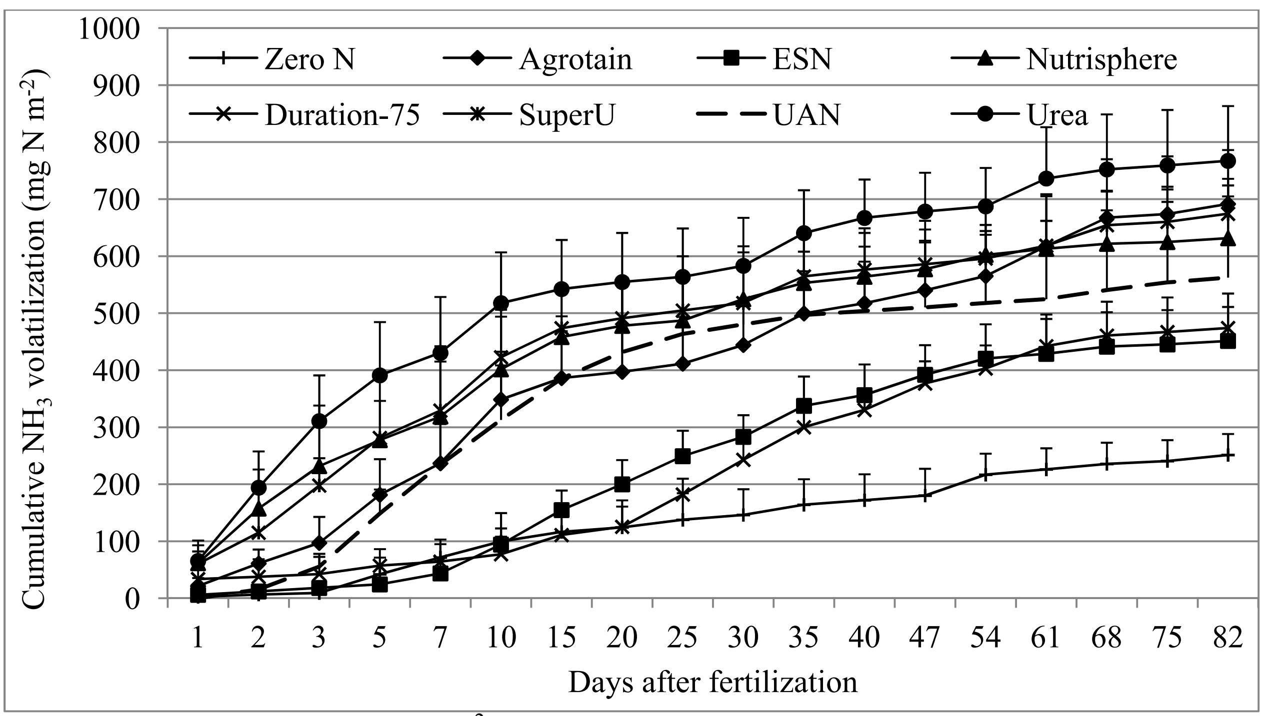

Figure 3. 2010 N loss (mg N m^{-2}) via ammonia volatilization from maize fertilized with enhanced efficiency urea products, untreated urea, or UAN.

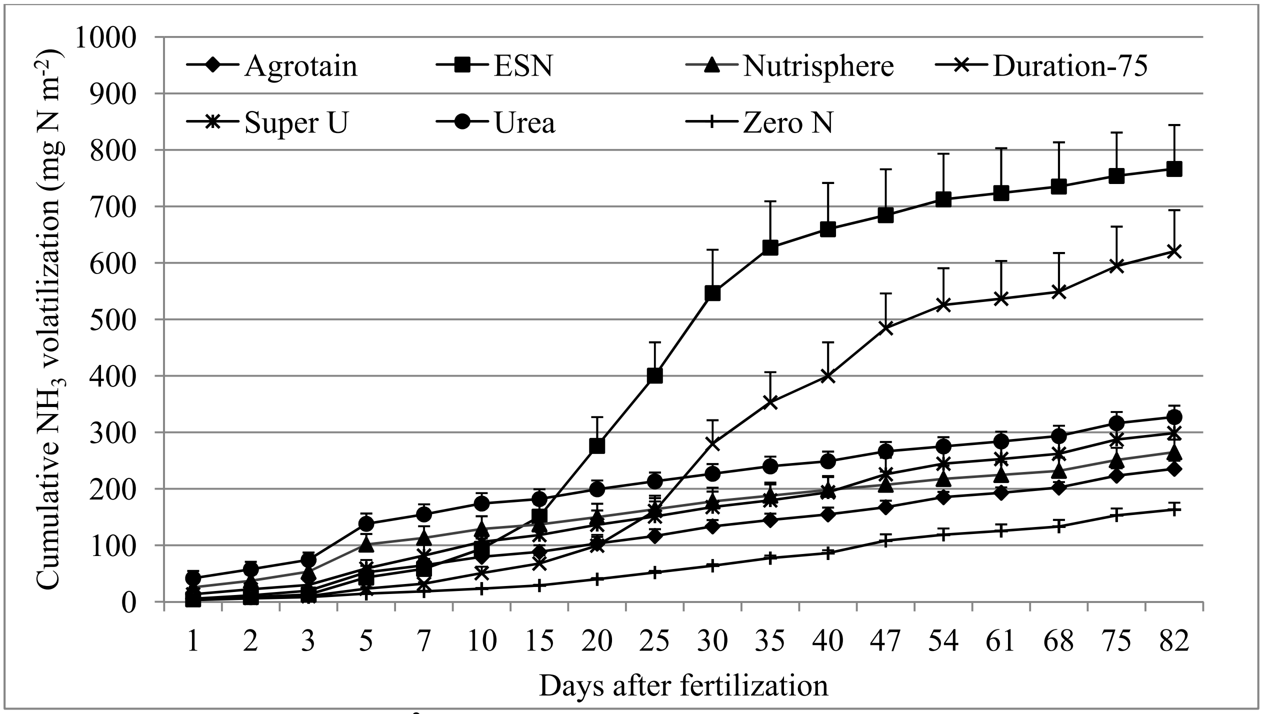

Figure 4. 2011 N loss (mg N m^{-2}) via ammonia volatilization from maize fertilized with enhanced efficiency urea products or untreated urea.

PROCEEDINGS OF THE

42^{nd}

NORTH CENTRAL EXTENSION-INDUSTRY SOIL FERTILITY CONFERENCE

Volume 28

November 14-15, 2012
Holiday Inn Airport
Des Moines, IA

Program Chair:

David Franzen
North Dakota State University
Fargo, ND 58108
(701) 231-8884
David.Franzen@ndsu.edu

Published by:

International Plant Nutrition Institute
2301 Research Park Way, Suite 126
Brookings, SD 57006
(605) 692-6280
Web page: www.IPNI.net