W 1322

Soil Properties that Affect Ammonia Volatilization Loss from Urea Ammonium Nitrate

Nutifafa Adotey, Assistant Professor and Soil and Nutrient Management Specialist, Department of Biosystems Engineering and Soil Science
Samuel Okai, Graduate Student, Department of Biosystems Engineering and Soil Science
Forbes R Walker, Professor and Environmental Soil Specialist, Department of Biosystems Engineering and Soil Science
Daniel Yoder, Professor, Department of Biosystems Engineering and Soil Science
Xinhua Yin, Professor and Cropping System Scientist, Department of Plant Sciences
Lori Allison Duncan, Assistant Professor and Row Crop Sustainability Specialist, Department of Biosystems Engineering and Soil Science
Debasish Saha, Assistant Professor, Department of Biosystems Engineering and Soil Science

Urea ammonium nitrate (UAN) solution (32-0-0) is produced from ammonium nitrate and urea. Urea ammonium nitrate is approximately 33 percent urea, 43 percent ammonium nitrate and 25 percent water and other materials (Nieuwenhuyse, 2000). Surface application of UAN is prone to significant losses of N to the atmosphere through ammonia volatilization (a gaseous loss of fertilizer N as ammonia) if these fertilizers are not incorporated into the soil. No-till (NT) or minimum tillage management is widely adopted in Tennessee to reduce soil erosion and runoff and to improve soil health. However, ammonia volatilization is generally greater in NT systems because N fertilizers are surface-applied or broadcast and are not incorporated into the soil. Urea-based fertilizers are converted to ammonium (NH_4^+) when applied to the soil under conditions of adequate soil moisture, higher temperatures and the presence of the urease enzyme. The ammonium ion is subsequently converted to ammonia gas, which escapes to the atmosphere (Figure 1). Volatilization is increased if the ammonium is at the soil surface with substantial atmospheric access. Ammonia volatilization can contribute significantly to N loss from corn fields that have high N fertilizer recommendations. Generally, ammonia volatilization loss from surface applied urea-based fertilizers increases with N application rates and ultimately reduces corn yield (Table 1). Given the NT prevalence and increasing use of UAN or urea-based fertilizer in Tennessee agriculture, N volatilization may negatively impact the efficiency and economics of fertilizer applications.

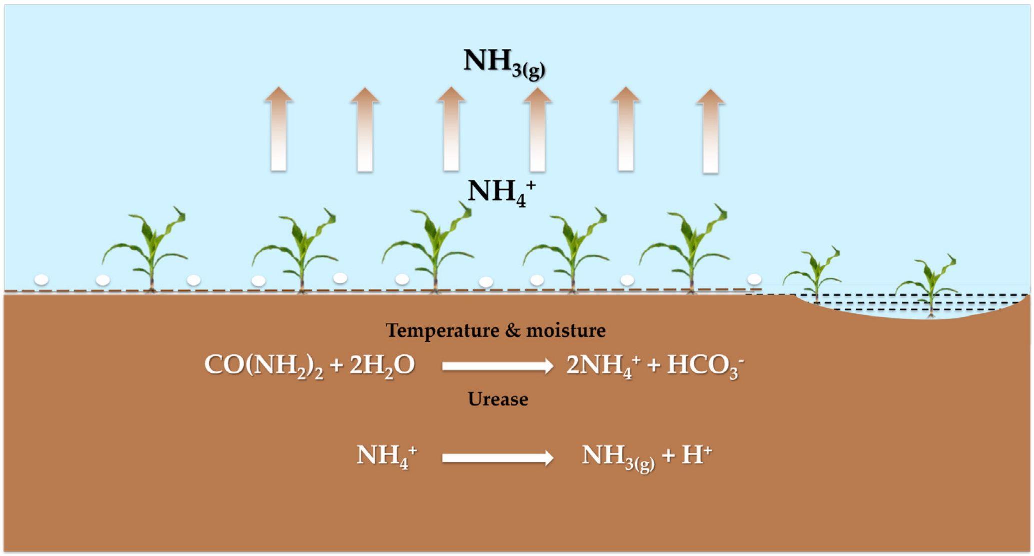

Figure 1. *Nitrogen loss through ammonia volatilization from urea-based fertilizers*

Table 1. Cumulative ammonia loss and corn grain yield of urea with and without nitrogen stabilizers (ANVOL™) applied at different N application rates

Nitrogen Rate (lbs. /acre)	Urea		Urea + ANVOL	
	Ammonia loss	Yield	Ammonia loss	Yield
	% applied N	bu/A	% of applied N	bu/A
0	<0.1	105	-	-
60	4.0	144	1.0	170
120	8.9	181	3.0	204
180	16.9	218	3.8	234
240	27.7	231	-	-

ANVOL™ is a nitrogen stabilizer.

Laboratory studies conducted on soils collected from eight fields in West Tennessee showed that up to 22 lbs. of the 120 lbs. N/acre (or 18 percent) of surface-applied UAN can be lost as ammonia (Figure 2) with most of the N lost via ammonia volatilization occurring within the first five days after application of urea-based fertilizer regardless of the soil type (Figure 3a). In this study, more than 90 percent of the total ammonia loss from surface applied UAN occurred within the first five days after fertilizer application (Figure 3b).

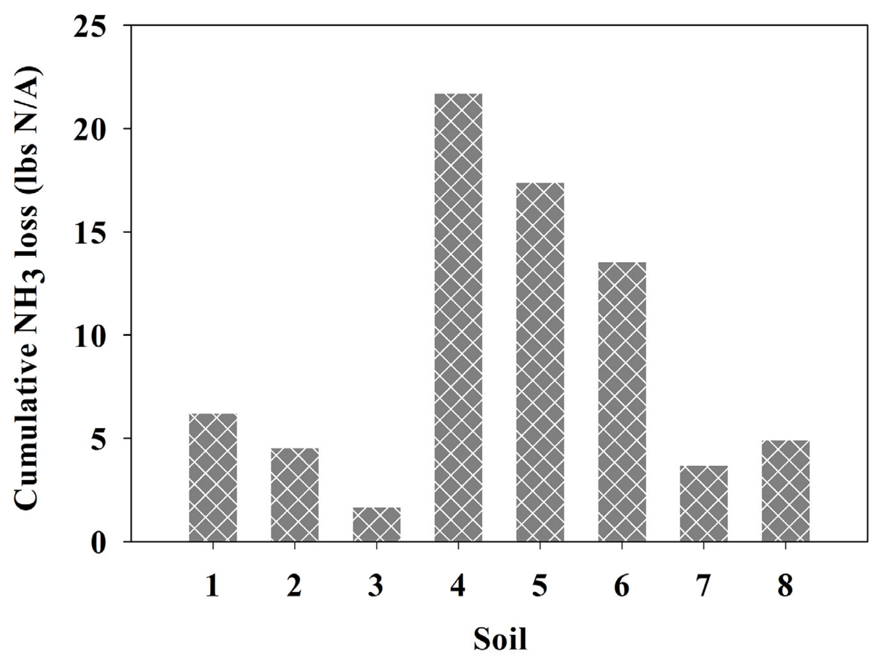

Figure 2. *Nitrogen loss through ammonia volatilization from urea-based fertilizers.*

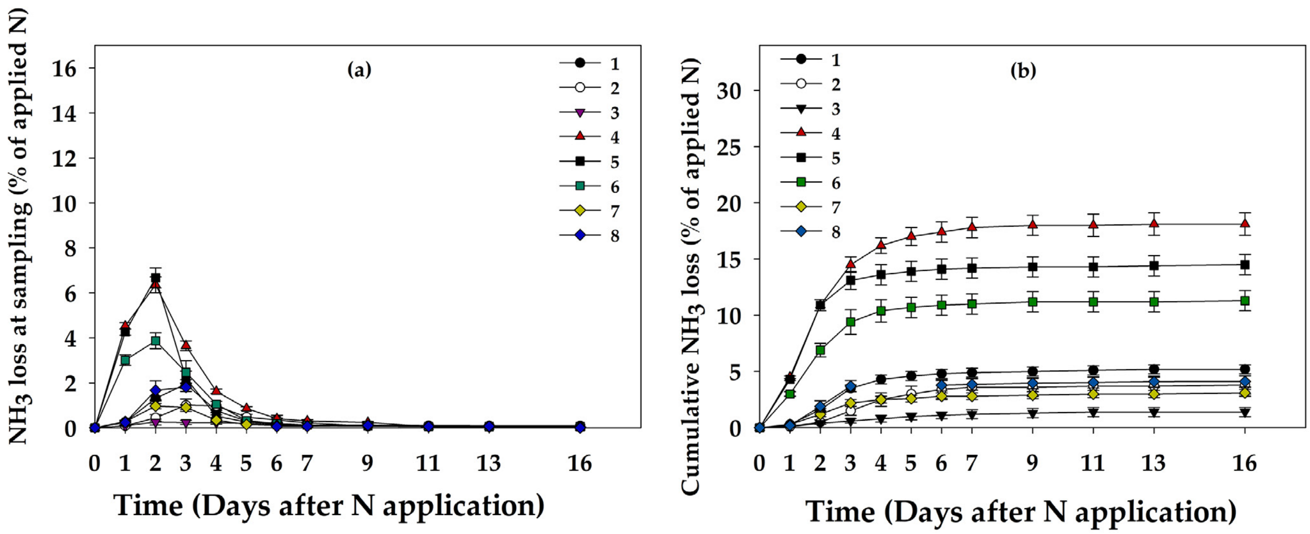

Figure 3. *(a) Ammonia loss at sampling and (b) cumulative ammonia loss from surface-applied UAN*

SOIL pH

Soil pH impact the availability of essential nutrients in the soil and impact ammonia loss from UAN. Generally, ammonia loss from UAN increases as soil pH increases (Figure 4a). The ammonium component of UAN is largely responsible for ammonia volatilization loss, with urea hydrolysis playing a less significant role. Low pH (<6) soils with their higher concentrations of H^+ ions favor the conversion of ammonia to ammonium ion, which minimizes ammonia loss. In contrast, higher pH soils are dominated by hydroxide (OH^-) ions, favoring the conversion of ammonium to ammonia gas before the onset of urea hydrolysis. This explains why in soils with pH greater than 7, the ammonia loss from UAN is very high and sometimes greater than losses from urea applied at the same rate. If UAN is applied onto a soil surface with pH greater than 7, farmers should use a proven N stabilizer. Information on N stabilizers evaluated in TN are available in the *UT Extension Publication PB1888 Enhanced Efficiency Fertilizers as a Tool to Control Nitrogen Loss in Row Crops Production* and *UT Extension Publication W1221Performance of Enhanced Efficiency Nitrogen Fertilizers and Sidedress Nitrogen Placement Methods in Dryland Corn*.

SOIL ORGANIC MATTER

Soil organic matter (SOM) refers to the decomposed stable component of organic matter in the soil. As with clay particles, SOM has large surface area and is negatively charged. Soil organic matter can also bind NH_4^+, thereby reducing the concentration of ammonium available for conversion to ammonia losses. Not surprisingly, therefore, soils with higher organic matter content were less susceptible to ammonia losses (Fig. 4b). Adopting management practices such as cover cropping and no-tillage can improve soil organic matter content and reduce N losses.

SOIL MOISTURE CONTENT

Field capacity is the soil water content after the soil has been saturated and allowed to drain freely for 24 to 48 hours. Ammonia loss from surface-applied, unincorporated UAN at or near field capacity decreases as the soil moisture increases (Figure 4c). In contrast, when UAN is applied onto a saturated or wet soil surface, ammonia loss increases significantly. Research shows that ammonia loss from surface-applied UAN on a saturated soil can be 10 times more than application at or near field capacity (Figure 5). This is because in saturated soils, the soil pores spaces are filled with water and thus the ammonia easily escapes to the atmosphere.

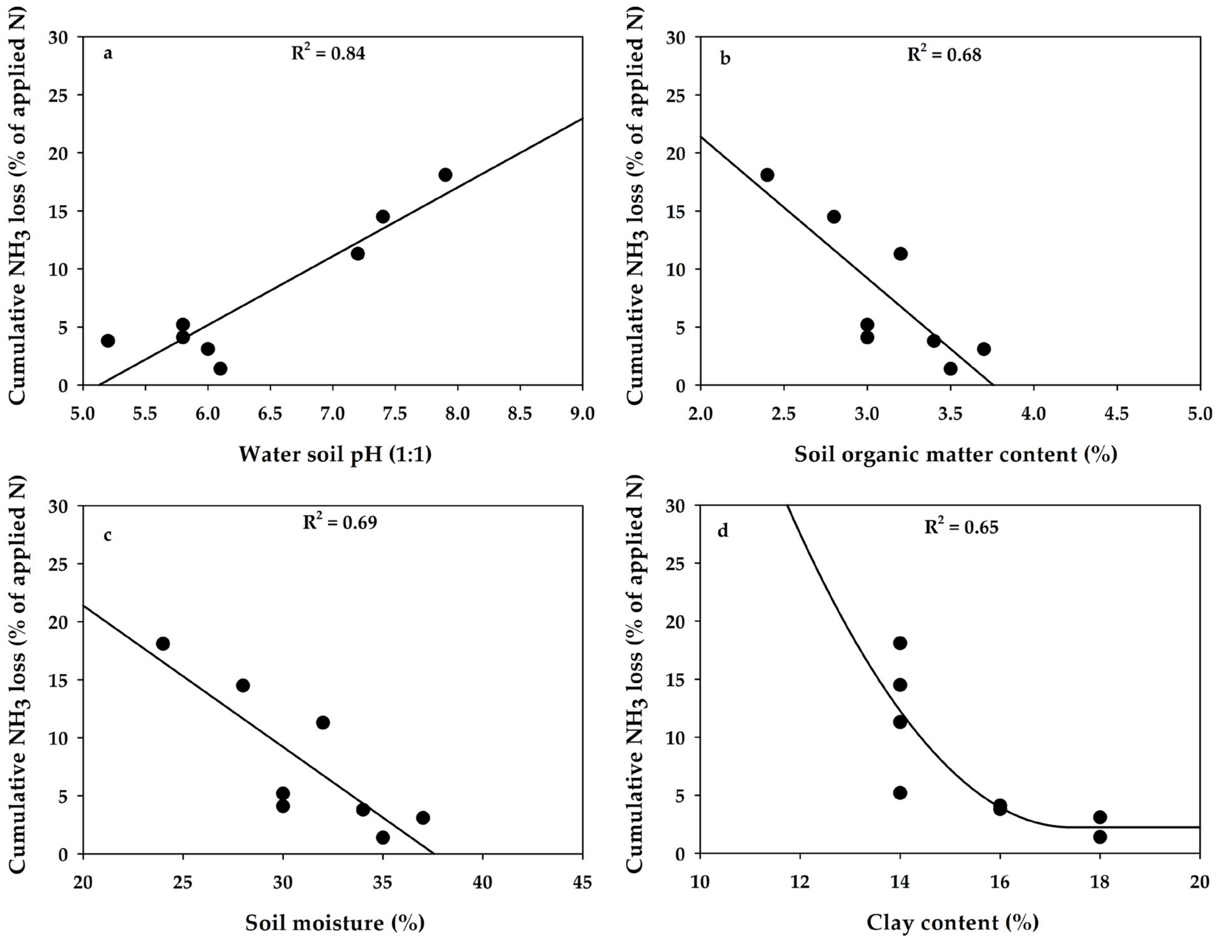

Figure 4. *Relationship between cumulative ammonia loss from eight soils 16 days after fertilizer application of surface applied urea ammonium nitrate and (a) clay content (b) soil pH (1:1), and (c) soil organic matter content, and (d) moisture content*

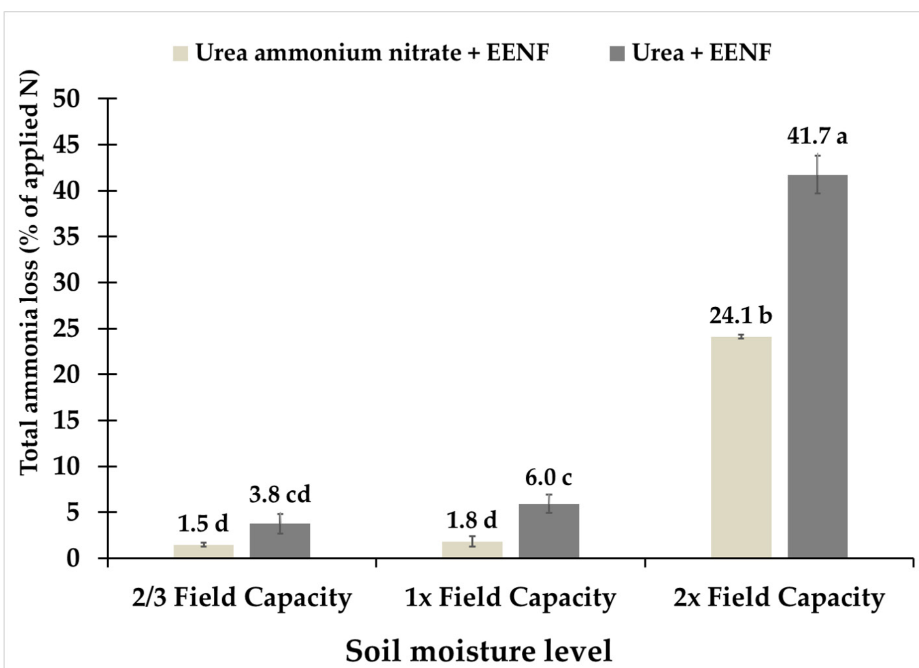

Figure 5.*Total ammonia loss from urea-based fertilizers at different soil moisture conditions.*

CLAY CONTENT

Clay content is the proportion of mineral soil particles with diameters less than 0.002 mm. Clays have large surface area and are negatively charged, so their surfaces can adsorb positively-charged cations such as NH4+. Cumulative NH3 losses from UAN decrease with increased clay content (Figure 4d). Soils with lower clay content have fewer negatively charged surfaces, so they retain less ammonium and much of the ammonium is available for conversion to ammonia. Since clay content is an inherent soil property and cannot be easily influenced by management practices, split application of urea-containing fertilizers can prevent substantial ammonia volatilization on sandy soils. In contrast, soils with higher clay contents are less susceptible to ammonia loss because of greater negatively charged surfaces, which retain ammonium.

SUMMARY

Soils with high pH (>7) had greater ammonia loss compared with soils of pH 6.0 to 6.2. Lower clay content soils, with lower SOM and lower soil moisture resulted in greater ammonia loss. The cumulative losses for UAN treatments were significant and had distinct correlations with all soil indicators tested. To reduce ammonia loss in soils that are susceptible to it, UAN should be treated with N stabilizer such as urease inhibitor.

This study was funded by the Tennessee Department of Agriculture.

RESOURCES MENTIONED

UT Extension Publication PB1888 Enhanced Efficiency Fertilizers as a Tool to Control Nitrogen Loss in Row Crops Production - tiny.utk.edu/EENF

UT Extension Publication W1221 Performance of Enhanced Efficiency Nitrogen Fertilizers and Sidedress Nitrogen Placement Methods in Dryland Corn - tiny.utk.edu/Research

FURTHER READING

Adotey, N., Kongchum, M., Li, J. Whitehurst, G. B., Sucre, E., & Harrell, D. L. (2017). Ammonia volatilization of zinc sulfatecoated and NBPTtreated urea fertilizers. Agronomy journal, 109(6), 2918-2926.

Dari, B., Rogers, C. W., & Walsh, O. S. (2019). Understanding factors controlling ammonia volatilization from fertilizer nitrogen applications. Univ. Ida. Ext. Bul, 926, 1-4.

Frame, W. (2017). Ammonia volatilization from urea treated with NBPT and two nitrification inhibitors. Agronomy journal, 109(1), 378-387.

Jones, C. A., Koenig, R. T., Ellsworth, J. W., Brown, B. D., & Jackson, G. D. (2007). Management of urea fertilizer to minimize volatilization. Montana State University Extension, 1-12.

Jones, C., Brown, B. D., Engel, R., Horneck, D., & Olson-Rutz, K. (2020). Factors affecting nitrogen fertilizer volatilization. Montana State University Extension. Online. landresources.montana.edu/soilfertility.

Zhou, X. V., Larson, J. A., Yin, X., Savoy, H. J., McClure, A. M., Essington, M. E., & Boyer, C. N. (2018). Profitability of enhanced efficiency urea fertilizers in no-tillage corn production. Agronomy journal, 110(4), 1439-1446.

UTIA.TENNESSEE.EDU

Real. Life. Solutions.™

W 1322 05/25 25-0401 Programs in agriculture and natural resources, 4-H youth development, family and consumer sciences, and resource development. University of Tennessee Institute of Agriculture, U.S. Department of Agriculture and County governments cooperating. UT Extension provides equal opportunities in programs and employment.