ENHANCED EFFICIENCY NITROGEN FERTILIZER AS A TOOL TO CONTROL NITROGEN LOSS IN ROW CROP PRODUCTION

Nutifafa Adotey, Assistant Professor and Extension Soil and Nutrient Management Specialist, Department of Biosystems Engineering and Soil Science

Angela McClure, Professor and Corn and Soybean Specialist, Department of Plant Sciences

Xinhua (Frank) Yin, Professor and Systems Agronomist, Department of Plant Sciences

INTRODUCTION

Fertilizer and lime applications represent about 20 percent of the total expenditure on most row crop farm budgets (***tiny.utk.edu/fieldcropbudgets***) in Tennessee. Nitrogen (N) fertilizer is used in the greatest amount and represents more than half of the fertilizer and lime expenditure. Given the substantial investment in N fertilizer there is a need to implement best management practices for efficiency and profitability of applications. Adopting sound management practices will reduce potential environmental risks associated with inappropriate N fertilizer application. A typical N management practice for most row crop producers in Tennessee is to split-apply a third of the recommended N at planting and sidedress the remaining N fertilizer. Figure 1 shows N uptake by the corn plant during the growing season, and the most active period of N uptake occurs at the V8 to V14 growth stage. Hence, sidedressing N in corn is recommended at V4 to V6 growth stage, which is closer to when the plants are actively taking up N. Considering that the majority of the N fertilizer is applied as sidedress, there is a greater risk for N loss depending on management practice, soil properties and environmental conditions.

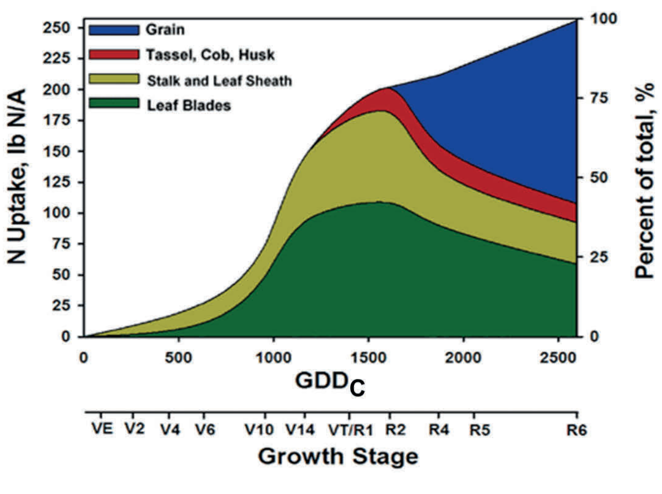


FIGURE 1. *Cumulative nitrogen (N) uptake by corn on a pound-per-acre basis and percentage from VE to R6. GDD_C, Growing degree days is the measure of heat accumulation and is used to estimate the growth and development of some agronomic crops. (Graph Source: Bender et al., 2013)*

One of the factors that influences the extent of N loss is the N fertilizer source. There are several N sources available for commercial row crop production. The International Plant and Nutrition Institute (IPNI) developed one-page fact sheets (***tiny.utk.edu/ipnifactsheets***) on the various N fertilizer sources and gives a review on their use. In Tennessee, urea and urea-based N fertilizers such as urea ammonium nitrate (UAN) are commonly used by row crop producers due to their economic advantage and minimal logistical constraints compared to other N sources. However, a major downside with urea and UAN is their susceptibility to N loss from ammonia volatilization. Understanding the major N loss pathways in row crops and the use of proven tools like Enhanced Efficiency Nitrogen Fertilizers (EENF) to minimize the risk of N loss is essential to maximize N fertilizer efficiency.

COMMON N LOSS PATHWAYS

Plants use N in the nitrate (***NO_3^-***) and ammonium (***NH_4^+***) forms. Most crops prefer NH_4^+ early and NO_3^- at late stages of plant growth. Many N forms present in soils and fertilizers are not readily available for plant uptake. These less available forms must be converted to NH_4^+ and NO_3^- through several physical, chemical and biological processes. For example, when urea or urea-based fertilizers are applied onto the soil, the urease enzyme accelerates the breakdown of urea into ammonium and hydroxide ions under adequate soil moisture and favorable soil temperatures. This process is referred to as ***urea hydrolysis***. Then, *Nitrosomonas sp.* bacteria in the soil can oxidize the ammonium into nitrite, which is further transformed into nitrate by Nitrobacter sp. bacteria through the process commonly referred to as nitrification (Figure 2). These plant available N forms (***NO_3^-*** and ***NH_4^+***) can be lost to the atmosphere or down the soil profile through several pathways. The major N loss pathways are ammonia volatilization, denitrification and nitrate leaching.

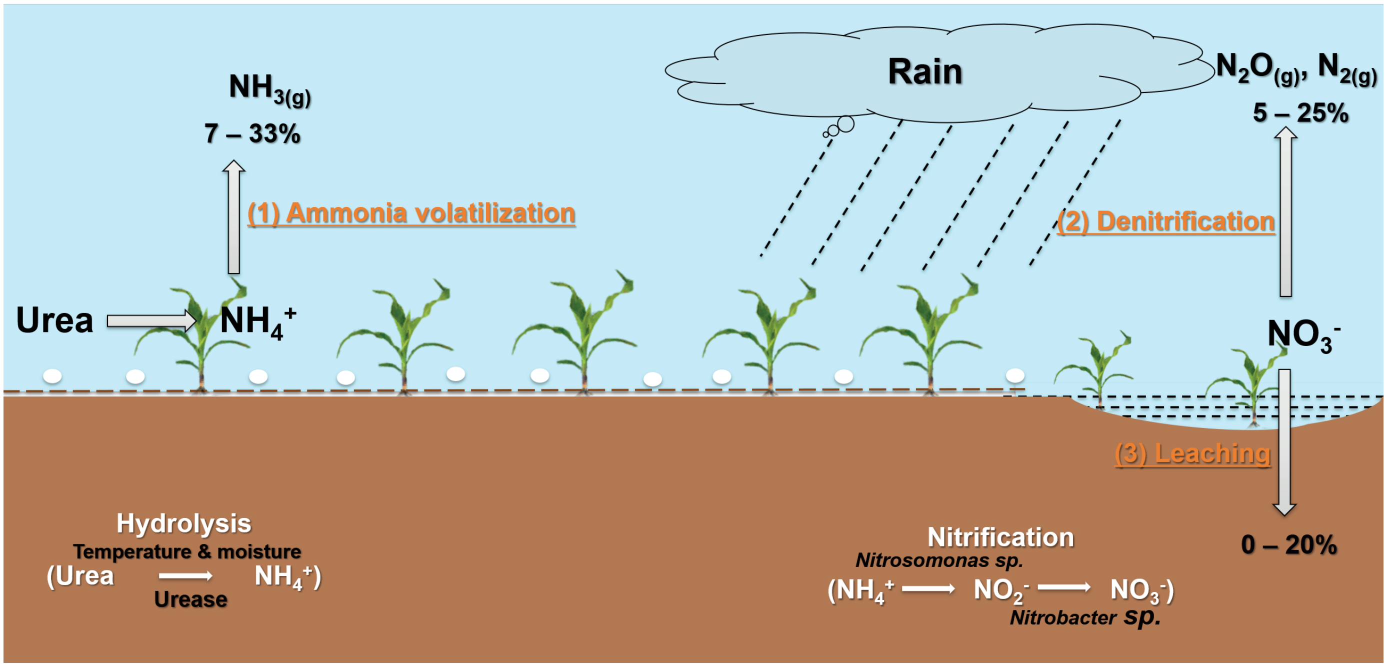


FIGURE 2. *Processes involved in the conversion of urea and urea-based fertilizer to plant available forms of N and different N loss pathways of these available forms of N*

Ammonia volatilization occurs when the ammonium released from surface applied urea or a urea-based fertilizer is converted into ammonia gas, which then escapes to the atmosphere. The greatest risk of ammonia loss occurs if the urea or UAN fertilizer sits on the soil surface without incorporation by rain, irrigation or tillage within a few days after application. Ammonia loss in row crops ranges from 7 percent to 33 percent from broadcast urea-based N fertilizers that are not incorporated into the soil. In general, higher soil moistures, temperatures, application of lime soon before application of urea fertilizer and a current soil pH above 7 will increase the ammonia volatility potential of urea-based fertilizers.

Denitrification is the conversion of nitrate into nitrous oxide or dinitrogen gas when the soil is ponded continuously for extended periods. The gases produced during denitrification escape into the atmosphere and reduce the amount of N available for plant use. The denitrification rate is greater in soils containing residue, which serve as food sources for the microbes. Depending on soil properties and environmental conditions, N loss via denitrification may account for 5-25 percent of the total N applied.

Nitrate (NO_3^-) is water soluble, loosely attached to the soil, and therefore susceptible to leaching once the soil is saturated. Soil nitrate that moves below 4 feet is unrecoverable by most crops and may contaminate ground water. In finer-texture soils with slow percolation, N loss via leaching may be negligible; but, in coarse texture soils where water percolates freely, 20 percent of applied N can be lost by leaching. Leaching is a greater risk if excessive rainfall occurs shortly after N fertilizer application when the concentration of nitrate in the soil is high. Soil properties such as texture, structure, bulk density and depth to restrictive layer play major roles in leaching potential. For further reading on nitrate leaching in Tennessee, refer to the UT Extension publication W 302 Assessing the Potential for Nitrogen Leaching from Your Tennessee Soils (***tiny.utk.edu/w302***).

WHAT ARE ENHANCED EFFICIENCY NITROGEN FERTILIZERS?

In Tennessee, most corn and cotton are grown in unirrigated no-till production systems that utilize urea and urea-based fertilizers. Therefore, a reliable approach to controlling N loss from ammonia volatilization is the use of enhance efficiency nitrogen fertilizers, or EENF. These fertilizers are prepared by chemically treating or physically coating the urea or UAN fertilizers. Enhanced efficiency fertilizers are grouped into two main categories: stabilized N fertilizers and slow release N fertilizers (Figure 3).

Stabilized N fertilizers

Stabilized N fertilizers contain one or more chemicals that extend the stability of a certain N form when compared to an untreated N fertilizer. Nitrogen stabilizers are chemicals added or used to treat N fertilizers to reduce ammonia volatilization and nitrification that play active roles in N loss. There are two types of N stabilizers, urease inhibitors and nitrification inhibitors.

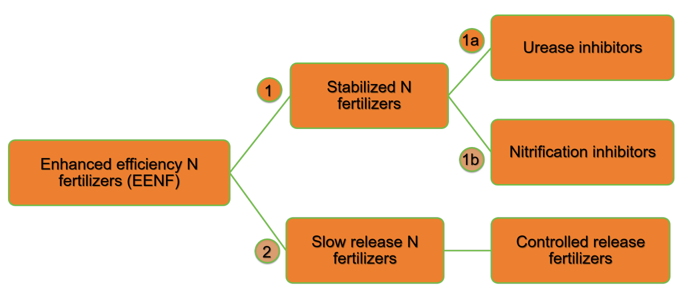


FIGURE 3. *Different types of EENF.*

Urease inhibitors minimize ammonia volatilization by temporarily inhibiting the function and activity of urease enzyme through competitive inhibition. N-(n-butyl) thiophosphoric triamide (NBPT) is regarded as one of the most effective urease inhibitors across different cropping systems. The NBPT works by binding to the active site of the urease enzyme which temporarily inhibits the ability of the urease enzyme to bind and hydrolyze urea until the NBPT degrades (Figure 4). There are several products on the market which contain NBPT at varied concentrations (Table 1).

Urease inhibitors are recommended if incorporation of urea or UAN into the soil by tillage, rainfall or irrigation is not possible or desirable within a few days after application. Treating urea-based N fertilizers with a urease inhibitor is also recommended when urea-based fertilizers will be applied onto a saturated soil without standing water. Urea treated with a urease inhibitor should not be applied into standing water because the urease inhibitor will not offer any protection against N loss. Urease inhibitors are not recommended for knifed-in UAN.

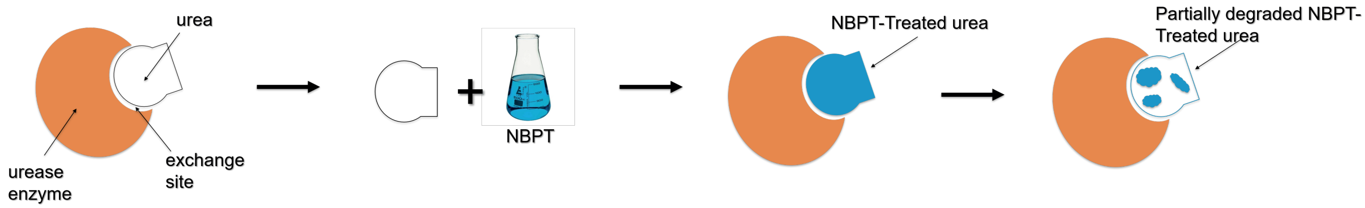


FIGURE 4. *Inhibitory action of NBPT.*

TABLE 1. *Product names, manufacturer, concentration of active ingredient, recommended rate and corn yield increase of N stabilizers.*

PRODUCT NAME	MANUFACTURER	CONCENTRATION OF ACTIVE INGREDIENT (S)	RECOMMENDED RATE (QT/TON)		CORN YIELD – TN (BU/A)	
			Urea	UAN	Urea	UAN
Urease inhibitors						
Agrotain® Ultra	Koch Industries	15-40% NBPT	3.0	1.5	+ 0 - 44 (24)	+ 25
Agrotain® Advanced	Koch Industries	15-40% NBPT	2.0	1.0	+ 27 - 28 (28)	+ 25
Arborite® Ag	Weyerhauser NR Co.	24.0% NBPT	3.0	1.5	-	-
ANVOL™	Koch Industries	10-20% NBPT & 20-30% Duromide	1.5	0.75	-	-
Limus®	BASF	<=18.8% NBPT & <=8.1% NPPT	3.0	1.5	-	-
Nitrification inhibitors						
Instinct II®	Corteva Agriscience	16.95% Nitrapyrin	N/A	37-74*	-	-
Centuro™	Koch Industries	<20% Pronitridine	N/A	6-10	-	-
Urease and nitrification inhibitors						
SuperU®	Koch Industries	<0.1% NBPT + 0.5-1.5% DCD	N/A	N/A	-	-

Numbers in the corn yield column represent the yield increase compared to the untreated urea or UAN fertilizer and the numbers in parenthesis is the average yield increase across year and location for each urease inhibitor. This excludes 2014 results from Springfield, TN (Figures 6 &7). Some of these products have not been evaluated in University of Tennessee research trials and their inclusion in this publication does not indicate endorsement"

The number in parenthesis is the average yield.

** Rate is fl oz per acre*

NBPT, N-(n-butyl) thiophosphoric triamide; DCD, dicyandiamide; N/A, not applicable

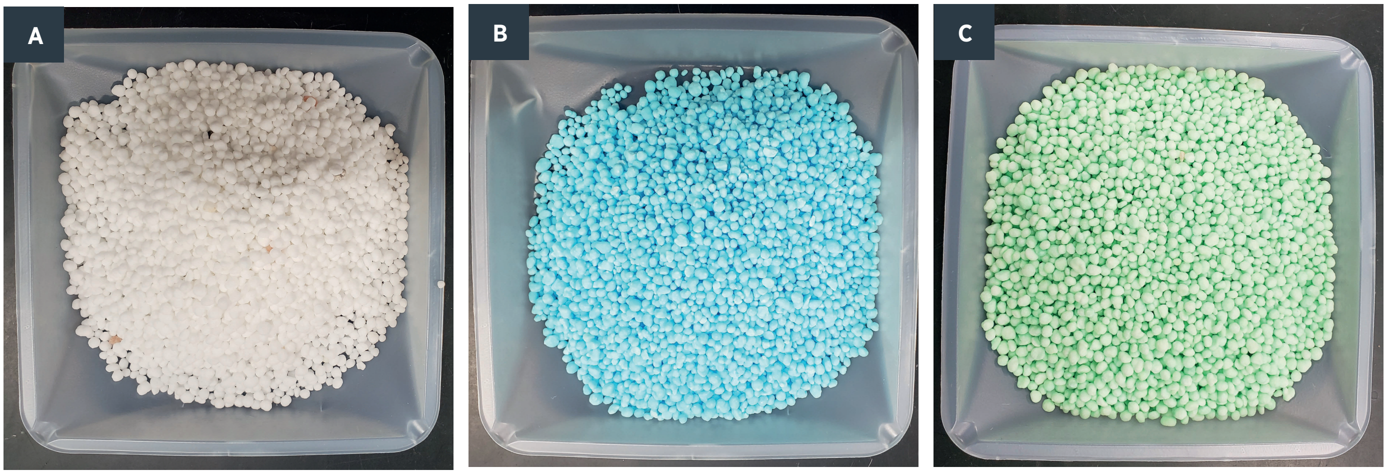


FIGURE 5. *Pictures of some stabilized N fertilizers; A) untreated urea, B) SUPERU [contains NBPT and DCD], and C) Urea treated with NBPT.*

Nitrification inhibitors temporarily delay nitrification by altering the activities of the ammonia-oxidizing bacteria (*Nitrosomonas spp.*) that catalyzes the conversion of ammonia into nitrite. This ensures that N is available in the ammonium form, hence providing protection against denitrification and leaching. Nitrification inhibitors are recommended for poorly drained fields that are prone to ponding or flooding for consecutive days after rainfall. Nitrapyrin and pronitradine are products with a known efficacy for inhibiting nitrification. Nitrapyrin is sold as N-Serve and pronitradine is marketed as Centuro. Some of the proven N stabilizer products on the market are listed in Table 1 and Figure 5.

SLOW RELEASE N FERTILIZERS

Slow release N fertilizers are products that slow the rate that the N becomes available over time compared to the conventional fertilizers. Controlled release fertilizers are a form of slow release fertilizer where the rate, pattern and duration of the N in fertilizer can be predicted. There are several ways these slow release fertilizers are manufactured or formulated; however, the predominant method is physically coating conventional fertilizer with water insoluble, permeable or semi permeable material such as polymer, resin, nutrient, etc. Slow or controlled release materials may provide protection against multiple N loss pathways: ammonia loss, denitrification and nitrate leaching. There is an added advantage in some cases to synchronize N release to meet crop demand. A commonly used polymer coated urea fertilizer is environmentally smart nitrogen (ESN). The semi-permeable layer allows soil moisture into the granule by osmosis, and this results in dissolution of nutrients within the encapsulated urea granule. The nutrients then diffuse into the soil slowly over time. The polymer is decomposed by microbes once the nutrients are released.

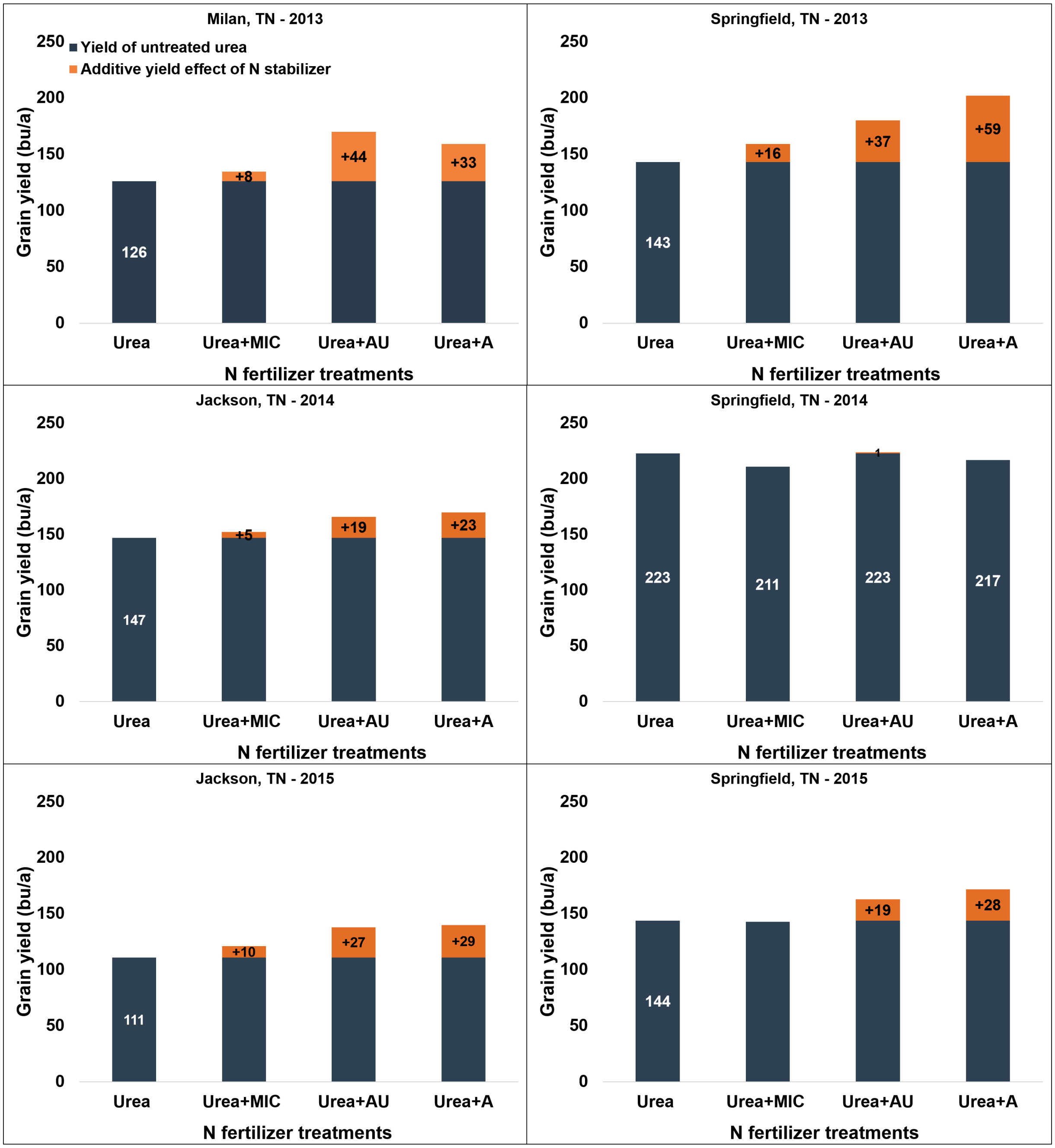
Unbiased field studies have been conducted in Tennessee to assess the performance of some EENF products under our growing conditions. Xinhua Yin, Hubert Savoy and other UT scientists evaluated the effect of urea treated with several urease inhibitors on corn yield. The results during 2013-2015 are reported in Figure 6. Yin also examined the addition of Agrotain products to UAN on corn yields in 2014 and 2015 (Figure 7). Urea fertilizers treated with urease inhibitors containing NBPT increased grain yield compared to the untreated urea. Corn yield for surface applied UAN treated with N stabilizers was higher than untreated UAN surface applied in 2015. Detailed information on these field trials is available at ***tiny.utk.edu/nitrogenloss***, ***tiny.utk.edu/w364*** and ***tiny.utk.edu/ammoniasci***. The publication titled ***W 828 Effects of Enhanced Efficiency Urea on No-tillage Corn Yield and Profit*** gives an excellent review on the profitability of enhanced efficiency N products in Tennessee.

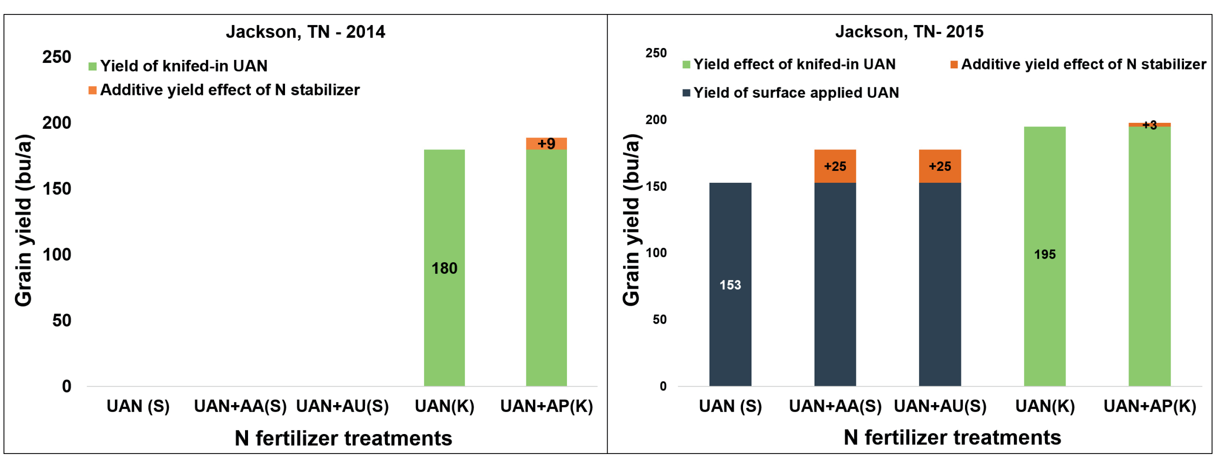
FIGURE 6, *above, page 5. Corn grain yield of surface applied urea treated with Agrotain products at Milan, Jackson and Springfield, Tennessee, during 2013-2015. Yield data is an average across 110 and 150 lb N/a application rates.*

MIC – maleic-itaconic copolymer; AU – Agrotain® Ultra, A – Agrotain®.

FIGURE 7, *below, page 5. Corn grain yield of surface and knifed-in UAN treated with Agrotain products at Jackson, Tennessee, in 2014 and 2015. Yield data is an average across 135 and 180 lb N/a application rates.*

UAN – Urea ammonium nitrate; S – surface applied; K – Knifed-in; AU – Agrotain® Ultra; AA – Agrotain® Advance; AP – Agrotain® Plus


Milan, TN - 2013
Yield of untreated urea
Additive yield effect of N stabilizer
Grain yield (bu/a)
250
200
150
100
50
0
126
+8
+44
+33
Urea
Urea+MIC
Urea+AU
Urea+A
N fertilizer treatments
Springfield, TN - 2013
143
+16
+37
+59
Jackson, TN - 2014
147
+5
+19
+23
Springfield, TN - 2014
223
211
223
1
217
Jackson, TN - 2015
111
+10
+27
+29
Springfield, TN - 2015
144
+19
+28


Jackson, TN - 2014
Yield of knifed-in UAN
Additive yield effect of N stabilizer
Grain yield (bu/a)
180
+9
UAN (S)
UAN+AA(S)
UAN+AU(S)
UAN(K)
UAN+AP(K)
N fertilizer treatments
Jackson, TN- 2015
Yield effect of knifed-in UAN
Additive yield effect of N stabilizer
Yield of surface applied UAN
153
+25
+25
195
+3

CONCLUSION

Nitrogen is needed for optimal crop yield. N losses are unavoidable, so it is extremely important for a producer to manage N fertilizer applications to increase the N use efficiency. One useful tool available to minimize N loss, avoid yield loss, and minimize environment pollution is the use of enhanced efficiency nitrogen fertilizers. There are several types of these N fertilizers available on the market. Some control just a particular type of N loss pathway while some provide protection against multiple N loss pathways. Weather, in particular rainfall, dictate the dominant N loss pathway in a growing season, so producers should factor-in weather considerations when deciding on the type of EENF to use. Producers should monitor projected weather conditions at the time of fertilizer application and through the periods of peak N uptake by plant when considering which EENF products will provide the most benefit in reducing N losses.

ADDITIONAL RESOURCES

Liu, S., X. Wang, X. Yin, H.J. Savoy, M.A. McClure, and M.E. Essington. 2019. Ammonia Volatilization Loss in Corn Nitrogen Nutrition and Productivity with Efficiency Enhanced UAN and Urea under No-tillage. Scientific Reports, 9:6610. ncbi.nlm.nih.gov/pmc/articles/PMC6488641/.

Nelson, D.W., and D. Huber. Nitrification Inhibitors for Corn Production. Corn National Handbook Project. Iowa State University Extension and Outreach. store.extension.iastate.edu/product/2921.

Roberts T., R. Norman, N. Slaton, and L. Espinoza. Nitrogen Fertilizer Additives. University of Arkansas Division of Agriculture, Research and Extension, FSA2169. uaex.edu/publications/pdf/FSA-2169.pdf.

Trenkel M.E. Slow-and controlled-release and stabilized fertilizers: An Option for Enhancing Nutrient Use Efficiency in Agriculture. 2nd ed. Paris, France: International Fertilizer Industry Association. fertilizer.org/images/Library_Downloads/2010_Trenkel_slow%20release%20book.pdf.

Savoy, H., and X. Yin, and M.A. McClure. 2016. Summary of Current University of Tennessee Institute of agriculture Research Evaluating Urea-Nitrogen-Fertilizer Additives or Coatings. University of Tennessee Publication, W364. extension.tennessee.edu/publications/Documents/W364.pdf.

Walker, F., and S. Hawkins. 2013. Assessing the Potential for Nitrogen Leaching from your Tennessee Soils. UT Extension publication, W 302. utbfc.utk.edu/Content%20Folders/Forages/Forage-Environmental%20Awareness/Publications/W302.pdf.

Zhou, X., J.A. Larson, X. Yin, H.J. Savoy, M.A. McClure, M.E. Essington, and C. Boyer. 2019. Effects of Enhanced Efficiency Urea on No-tillage Corn Yields and Profit. UT Extension publication, W828. ncbi.nlm.nih.gov/pmc/articles/PMC6488641/.

UTIA INSTITUTE OF AGRICULTURE
THE UNIVERSITY OF TENNESSEE

UTIA.TENNESSEE.EDU

Real. Life. Solutions.™

PB 1888 10/20 21-0049