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Improving the Efficient Use of Urea-Containing Fertilizers

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Summary: Surface-applied urea fertilizers can result in some nitrogen being lost to the air as ammonia. Losses are more likely and greater in magnitude in no-till cropping systems and when temperatures are warm. Incorporate urea fertilizers into the soil whenever possible to reduce nitrogen loss to negligible levels. If surface applications must be made, band rather than broadcast the fertilizer to encourage movement into the soil and reduce ammonia loss. Use a strong urease inhibitor with broadcast applications of urea fertilizers. Avoid preplant applications of urea fertilizers unless a nitrification inhibitor is used slow the formation of nitrate-nitrogen which would be subject to leaching and denitrification.

Introduction

Urea is a 46% nitrogen (N) fertilizer that may be added to soils alone or in combination with other N fertilizers. The most common example is liquid nitrogen fertilizer (UAN) which is approximately half urea and half ammonium nitrate and ranges from 28% to 32% N by weight.

Conversion of urea to ammonium is necessary before substantial amounts of N can be accumulated by the crop root system. This conversion, termed urea hydrolysis, is accomplished by urease enzyme. Urease is prevalent on crop residues and in soil so hydrolysis occurs readily with warm temperatures and adequate moisture.

Unfortunately, if urea remains on the surface of residues or soil some of the ammonium can be converted to ammonia which can be lost to the air. This process is called ammonia volatilization (AVOL) and is the primary factor reducing the effectiveness of urea as a surface-applied fertilizer. Under the worst of conditions up to 60% of the N in urea can be lost by AVOL, however losses of less than 30% are more common. Since half of UAN is comprised of urea, AVOL losses from UAN are typically about half that of urea.

Soil and environment factors affecting ammonia volatilization

The most effective way to eliminate AVOL is to place urea into the soil at least an inch or two deep with a knife or coulter applicator. Incorporation of urea into the soil can also occur via rainfall or irrigation, but only prior to hydrolysis. With warm temperatures, >85 °F, the window for incorporation by rainfall may be as little as 24 hours. Cold temperatures, like those around wheat topdressing time, slow urea hydrolysis so there is more opportunity for rain to move the urea into the soil. This is why urea and UAN have been traditionally used for topdressing wheat with little concern for AVOL.

If urea cannot be incorporated into the soil, then understanding the factors affecting AVOL will help get the most from the N applied. The most important factor affecting AVOL is the pH around the urea compound. The higher the pH, the higher the potential for AVOL. Unfortunately the hydrolysis of urea creates its own high pH environment, climbing above 9 on sandy soils or on crop residues. The soil's resistance to pH change, or buffer capacity, is the most important soil factor affecting AVOL when urea is left the soil surface. Soils high in clay content, cation exchange capacity and organic matter have high buffer capacity (a strong resistance to pH change) and therefore low AVOL. Sandy soils, low in cation exchange capacity and organic matter, have high potential for AVOL because of low buffer capacity. Likewise, crop residues have low buffer capacity. Although the initial pH of the soil and the presence of surface applied lime may have some impact on AVOL these factors are much less important than the buffer capacity of the soil.

Banded versus broadcast applications of urea

If UAN must be applied and left on the soil surface it is much better applied in a narrow band than broadcast. Banding allows more of the material to runoff residues and penetrate deeper into the soil. Band application of granular urea, rather than a broadcast application, reduces AVOL by slowing the conversion of urea to ammonia.

Urease inhibitors for surface application of urea

Several compounds inhibit urea hydrolysis for a short period of time. The most commonly known and commercially available are NBPT [N-(n-butyl) thiophosphoric triamide], NPPT [n-propyl thiophosphoric triamide], and ATS (ammonium thiosulfate). The effect of these inhibitors is to delay hydrolysis so there is a greater chance for rainfall to occur and move the urea into the soil. ATS is a weak urease inhibitor so its effectiveness is quite limited. NBPT and NPPT are much more effective than ATS, delaying hydrolysis for a week or so. Even though using a urease inhibitor with surface-applied urea and UAN is beneficial, injecting UAN is generally more effective at reducing AVOL.

Incorporated urea as a spring substitute for anhydrous ammonia

Even when incorporated into the soil urea can at times be an inferior substitute for anhydrous ammonia. Urea converts faster to nitrate than anhydrous ammonia so it is susceptible to leaching and/or denitrification losses for a longer period of time than anhydrous ammonia. Using a nitrification inhibitor, such as nitrapyrin or dicyandiamide (DCD), with preplant urea can slow the conversion to nitrate and reduce nitrogen loss from leaching and denitrification.

Leaching of urea

Urea is a molecule without charge. It is neither attracted to the cation or anion exchange sites occurring in soil. Urea moves with the percolating water until it is hydrolyzed to ammonium. Rainfall shortly after application can incorporate the urea into the soil and reduce ammonia volatilization losses, but occasionally high rainfall shortly after application of urea will result in its leaching from the rootzone in sandy soils. The amount of nitrogen lost from the rootzone is dependent on the percentage of nitrogen in the urea form, soil type, the amount of rainfall in relation to evapotranspiration, and the depth of the rootzone. Although this type of N loss is unusual, it is encountered occasionally.

Summary

Surface-applied urea fertilizers can result in some nitrogen being lost to the air as ammonia. Losses are more likely and greater in magnitude in no-till cropping systems and when temperatures are warm. Incorporate urea fertilizers into the soil whenever possible to reduce nitrogen loss to negligible levels. If surface applications must be made, band rather than broadcast the fertilizer to encourage movement into the soil and reduce ammonia loss. Use a strong urease inhibitor with broadcast applications of urea fertilizers. Avoid preplant applications of urea fertilizers unless a nitrification inhibitor is used slow the formation of nitrate-nitrogen which would be subject to leaching and denitrification.

Literature used in preparation of this document

Factors Affecting Urea Hydrolysis. 1988. D.E. Kissel and M.L. Cabrera. In B.R. Bock and D.E. Kissel (ed.) Ammonia volatilization from urea fertilizers. Bull. Y-206. National Fertilizer Development Center, TVA, Muscle Shoals, AL.

Soil, Environmental, and Management Factors Influencing Ammonia Volatilization under Field Conditions. 1988. W.L. Hargrove. In B.R. Bock and D.E. Kissel (ed.) Ammonia volatilization from urea fertilizers. Bull. Y-206. National Fertilizer Development Center, TVA, Muscle Shoals, AL.

Tri-State Fertilizer Recommendations for Corn, Soybeans, Wheat & Alfalfa. 1995. M.L. Vitosh, J.W. Johnson, and D.B. Mengel. Ext. Bull. E-2567. [URL accessed June 2017] https://www.extension.purdue.edu/extmedia/AY/AY-9-32.pdf

Urea and Anhydrous Ammonia Management for Conventional Tillage Corn Production. 1990. R.C. Stehouwer and J.W. Johnson. J. Prod. Agric. 3:507-513.

Nitrogen Extenders and Additives. 2017. D.W. Franzen and NCERA-103 Committee. North Dakota State Univ. Ext. Serv. SF1581. [URL accessed June 2017]. https://www.ndsu.edu/fileadmin/soils/pdfs/Nitrogen_Extenders_and_Additive_for_Field_Crops_2017.pdf