CORN SEEDLING INJURY FROM AMMONIA

John Sawyer, Professor, Department of Agronomy, Iowa State University

A considerable amount of anhydrous ammonia was spring preplant applied this year in Iowa. In addition, I had several calls about banding urea and what that might mean for corn seedling injury. From past experience we know that occurrence of injury is less in springs when soils remain moist but increases with dry spring conditions. What occurs that results in seedling and root injury?

Injection of anhydrous ammonia

When anhydrous ammonia is injected into soil, several physical and chemical reactions take place: dissolution in water, reaction with soil organic matter and clay, and attachment of the resulting ammonium ions on the cation exchange complex. These reactions all tend to limit the movement of ammonia. The highest concentration of ammonia is at/near the point of injection, with a tapering of the concentration toward the outer edge of the retention zone. Usually the greatest ammonia concentration is within the first inch or two of the injection point, with the overall retention zone being up to 3-4 inches in radius (as an example, with 120 lb N/acre applied early April at Urbana IL, the ammonium-N concentration in mid-May was at approximately 700 ppm at 0-1 inch, 300 ppm at 1-2 inch, and 25 ppm at 2-3 inch from the injection point). Another example of the ammonium concentration and soil pH at the center of an ammonia zone is given in Figure 1. The size of the ammonia retention zone, and shape, vary greatly depending upon the rate of application, knife spacing, the soil, and soil conditions at injection (soil texture, soil structure, organic matter, and moisture status). Because of the resultant concentration and pH gradient, the greatest potential for root/seedling injury (see photos) is the center part of the injection zone. Also, nitrification initially proceeds more rapidly at the edges of the injection zone, which reduces the ammonium concentration.

Ammonia moves farther at injection in coarse-textured soils and soils low in moisture. Also, if the injection knife causes sidewall smearing (when soils are wet), then ammonia may preferentially move back up the knife slot. Movement toward the soil surface can also occur for some time after application if the soil dries and the knife track “opens up” as the soil dries (also less soil moisture to retain free ammonia in solution with drying soils). This is likely a main cause for seedling injury in dry springs when the injection depth at application seemed adequate. A similar movement within the soil can occur if the soil breaks into clods at application and there are large air voids left in the soil. Both of these conditions can result in greater ammonia concentration toward the soil surface, and greater potential for seedling injury and losses to the atmosphere at or after application (the same if the injection point is near the soil surface).

When ammonia is injected into soil, the initial reaction at the point of release is violent. The ammonia reacts and binds with soil constituents such as organic matter and clays. It reacts with water to form ammonium (NH_4^+). These reactions help retain ammonia at the injection point. With the high affinity for water, soil moisture is important for limiting the movement of ammonia, but does not ultimately determine retention in soil. After conversion to ammonium,

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which is a positively charged ion, it is held on the soil exchange complex and does not move with water. Only after conversion to nitrate (NO_3^-), via the nitrification process, can it be lost from soil by leaching or denitrification.

Ammonia reactions in soil

a) $NH_3 + H_2O = NH_4^+ + OH^-$

This is the initial ammonia reaction with water and causes an alkaline pH in the ammonia retention zone (pH can rise above 10.0 at the point of highest concentration). It is free ammonia and not ammonium that can be lost from soil and is damaging to microorganisms and plant roots/seedlings. As pH goes above 7.3, the equilibrium between ammonium and ammonia results in increased ammonia (the percentage as ammonia would be 1% at pH 7.3, 10% at pH 8.3, and 50% at pH 9.3).

b) $2NH_4^+ + 3O_2 \Rightarrow 2NO_2^- + 2H_2O + 4H^+$

c) $2NO_2^- + O_2 \Rightarrow 2\ NO_3^-$

These two reactions are the steps in the nitrification process that occurs with ammonium in soil, and ultimately results in a lowering of pH back to the original pH or lower. Nitrification occurs first at the outer edges of an ammonia band, and progresses inward as the initial effects of ammonia injection decrease and the soil conditions become more conducive to microbial growth.

The reactions outlined above also occur when urea is applied to the soil. An additional and initial reaction is conversion (hydrolysis) of urea to ammonium (see reactions given below), which is increased greatly by the urease enzyme. When urea is banded in a concentrated zone, the initial ammonium and ammonia concentrations are very similar to that in an anhydrous ammonia band. The magnitude of concentration and formation of ammonia is also dependent on the rate of N applied.

Anhydrous ammonia application to dry soils

Can anhydrous ammonia be applied to dry soils? Yes. Despite what people may think, dry soil can hold ammonia. Ammonia dissolves readily in water, but it is held or retained in soil by clay and organic matter. The problem with dry soil and low moisture is that soil moisture is needed to temporarily hold the ammonia so it can become attached to clay or organic matter. If dry soils are cloddy and do not seal properly, the ammonia can be lost at injection, or seep through the large pores between clods after application. Therefore, proper depth of injection and good soil coverage are a must for application into dry soils. Wing sealers immediately above the outlet port on the knife can help close the knife track, limit the size of the retention zone, and reduce vertical movement of ammonia.

Ammonia injury to corn seedlings

Injury comes from the unionized (free) ammonia (NH_3) either in the soil water (aqueous ammonia) or in the soil atmosphere. The activity of NH_3 in solution that can cause root injury is very low (0.17 mM). The potential is usually small for fall-applied ammonia to damage corn seed or seedlings. However, if the soil remains dry (and limits nitrification), the ammonia is injected shallow or there is poor soil structure (ammonia placed near the seed location), or the rate of application is high, then it is possible for ammonia damage to occur. The potential for

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injury from spring application goes up due to the shorter period from application to planting. The best cure is to inject deep enough with friable soil coverage to get adequate soil separation between the point of ammonia injection and the depth where corn seed will be planted. For example, if the injection point is 6 to 8 inches in depth, the outer edge of the ammonia retention zone (which would be low in ammonia concentration) is about 3 to 4 inches from the point of injection, and seed is planted at a 2-inch depth directly over the ammonia track, then the seed would be outside or at the edge of the applied ammonia band. Roots growing toward/into the ammonia band center could be injured when the seed/seedling is not. Shallower injection, greater ammonia movement upward from the injection point, wider knife spacing, or higher N rates can lead to ammonia being placed in the seeding area at concentrations high enough to cause injury. Also, injury tends to be more common in dry soil conditions because of slower overall root system development.

Urea reactions in soil

When urea is applied to soils, the three initial reactions shown below take place. The consumption of hydrogen ions (H^+) means there is an increase in soil pH. If urea is broadcast on the soil surface (or especially onto crop residue), ammonia produced can be lost to the atmosphere as indicated by reaction 3 (see equations above also).

1) $(NH_2)_2CO$ (urea) + $2H_2O$ = $(NH_4)_2CO_3$ (ammonium carbamate)
2) $(NH_4)_2CO_3 + 2H^+ = 2NH_4^+ + CO_2 + H_2O$
3) $NH_4^+ + OH^- = NH_3 + H_2O$

If urea is banded in the soil, then the magnitude of the pH increase and the production of free ammonia are greater due to concentration into a band (Figure 2) versus diffuse individual granules spread across/within the soil. The magnitude of this effect is also rate related. It is this production of ammonia, along with osmotic potential increase (salt level), that results in root/seedling injury. These reactions and potential for free ammonia are the reasons banding even low rates of urea with the seed is discouraged (see photo) and suggested rates for bands near corn seed (such as 2 x 2 starter) are lower than for other N fertilizers.

Summary

Anhydrous ammonia and urea are good N fertilizer sources. With proper management, and help from Mother Nature, most fields do not experience crop injury issues from use of these materials. However, sometimes problems arise due to a variety of reasons. Potential for crop injury can be greatly reduced by not matching corn rows with ammonia tracks and urea bands. Having soil separation is key; so applying at an angle, good injection depth, good soil conditions at application, or use of RTK GPS (real time kinematic GPS) to place bands away from future corn rows.

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Figure 1. Soil pH and ammonium-N concentration at the center of the ammonia band (highest concentration point).

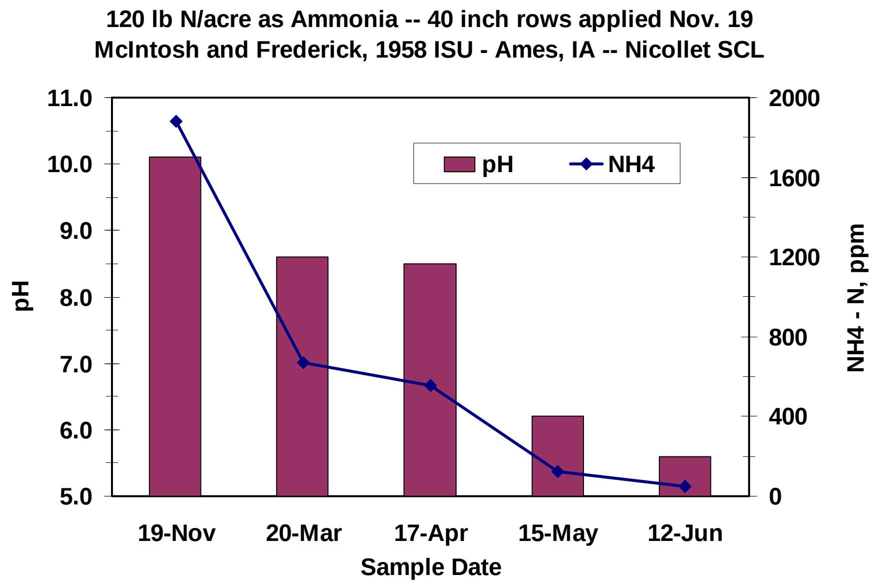
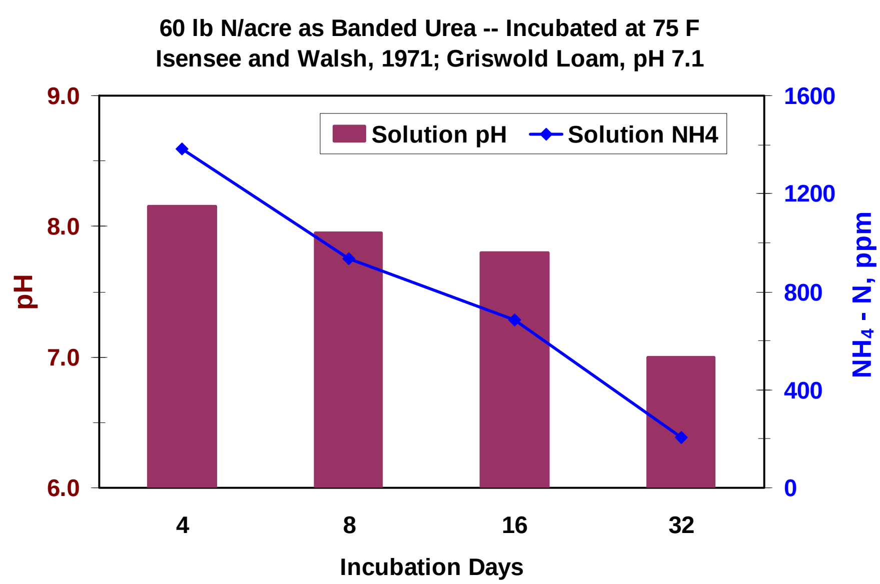


Figure 2. Soil solution pH and ammonium-N concentration with banded urea.



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Seedlings showing the effect of root injury from ammonia.

Corn root/seedling damaged by ammonia.

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Corn stand loss from urea banded with the seed at 10 lb N/acre.

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