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Fall Fertilizer Nitrogen Application

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Abstract

Fall nitrogen (N) fertilizer application continues to be popular for several reasons, including lower cost, time for application, equipment availability, often better soil conditions, and competing springtime field activities. Success, compared to spring or sidedress timing, can be enhanced by following several long-standing suggestions: only use anhydrous ammonia; apply in late fall after soils cool to 50 degrees F (4-inch depth) and are trending cooler (the colder the better); consider an effective nitrification inhibitor to further slow nitrification to nitrate; and avoid fall application to soils that are more prone to wetness or leaching (poorly or excessively drained soils).

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Nitrification inhibitors should be considered a component of fall anhydrous ammonia management. Nitrification inhibitors work by slowing, not stopping, activity of nitrifying bacteria and hence slow nitrification (ammonium conversion to nitrate). Nitrification inhibitors are more effective with cold temperatures, and thus delay nitrification longer when soils are cold. With warm temperatures, the inhibitors are also “degraded” quickly and hence loose effectiveness. Nitrification inhibitors can “pay” but not always. All depends on conversion to nitrate, when converted to nitrate, how effective the inhibitor, and if any major wet/loss conditions are “missed” because applied N is still in the ammonium form which is not subject to leaching or denitrification. Most nitrate loss occurs in the springtime months, so having ammonium present during those months is important. Fall applied N, to be more like a spring application, needs to have the applied N in an ammonium form – hence late fall application, cold soils, and a nitrification inhibitor consideration.

Other common N fertilizers, like granular urea and UAN (urea-ammonium nitrate solution), do not have the initial inhibitory effect on nitrifying bacteria like anhydrous ammonia, and therefore should not be fall applied. For example, research across many years at the ISU Northern Research Farm at Kanawha has documented lower corn yield with fall incorporated urea compared to spring incorporated urea. The co-nitrogen application in DAP and MAP can be at risk with fall application due to rapid nitrification (N in DAP and MAP is in the ammonium form), and with the often early fall application. Triple superphosphate is becoming more available in the Midwest, and is a phosphorus fertilizer option that does not contain N.

Where to find soil temperature information

Soil temperatures can be found at several web sites. One site gives the 3-day, 4-inch depth soil temperature estimates for each county, and the 6-10 day weather forecast. That site can also be accessed through the Agronomy Extension and Outreach Soil Fertility web site, either from the weather page or Nitrogen Topic page. The 4-inch soil temperatures are estimated for each county based on interpolation of observed soil temperatures at multiple locations. The estimates are for soil temperatures on level, bare soil. Maximum/minimum soil temperatures from ISU research farms are available from the same sources, and are useful for watching the impact of warm air on soil temperatures. If you are curious about this fall's past 4-inch soil temperatures (longer than 3 days ago), check this "IEM Time Machine" site.

What happens when anhydrous ammonia is injected into soil?

Several physical and chemical reactions take place: ammonia dissolution in water, reaction with soil organic matter and clay, and attachment of ammonium ions on the soil cation exchange complex. These reactions all tend to limit the movement of ammonia, with water having the greatest initial effect. 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 most soils. The shape and size of the ammonia retention zone vary greatly depending upon the rate of application, knife spacing, the soil type, and soil conditions at injection (soil texture, soil structure, organic matter, and moisture status).

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" (also due to less soil moisture to retain free ammonia in solution with drying soils). 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. These conditions can result in greater ammonia concentration toward the soil surface, and greater potential for loss to the atmosphere at or after application.

When ammonia is injected into soil, the initial reaction at the point of release is violent. 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, which is a positively charged ion, it is held on the negatively charged 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.

Chemical and biological reaction of anhydrous ammonia in soil over time

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

This initial chemical reaction of ammonia (NH_3) with water and causes an initial alkaline pH in the ammonia retention zone (pH can temporarily rise above 9 at the point of highest concentration). It is free ammonia and not ammonium that can be lost from soil at application and is damaging to microorganisms and plant seedlings. As pH goes above 7.3, the equilibrium between ammonium and ammonia results in increased aqueous "free" ammonia (the percentage as ammonia would be 1% at pH 7.3, 10% at pH 8.3, and 50% at pH 9.3).

2) $2NH_4^+ + 3O_2 = 2NO_2^- + 2H_2O + 4H^+$

3) $2NO_2^- + O_2 = 2NO_3^-$

These last two reactions are the steps in the biological nitrification process (energy source), 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.

Is there a maximum ammonia application rate that soils can hold?

The rate of anhydrous ammonia that can be held in soil is not a direct relationship with CEC. Soil properties affect the size of the injection zone, but ultimately several other factors are more important, such as moisture content, depth of injection, and soil coverage, especially with dry soil or coarse textured soil. Within agronomic rates of application, there is no real limit or maximum application rate. In research conducted with alternate row injection (example 60 inch spacing in 30 inch row corn), 200 lb N/acre has been successfully applied – which is an equivalent of 400 lb N/acre per injection knife. It is the injection depth, soil coverage, and overall soil conditions that determine retention, not simply CEC.

Bottom line

Be mindful of application date and soil temperature for fall anhydrous ammonia application, soil conditions, and what is happening at application if soil conditions are not ideal. If the soil is smearing, breaking into clods, there isn't good coverage of the knife track with loose soil, and ammonia is escaping (remember your nose tells you if ammonia is escaping; a white vapor is condensed water, not ammonia which is colorless), then stop and either change the way the equipment is working or is set up, or wait until the soil has better structure or moisture.

Category: Soil Fertility

Crop:

Corn

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