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Nitrogen Management for No-Tillage Systems in Missouri

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Research throughout the Corn Belt is providing increasing evidence of the value of producing corn without tillage. With most soils and rotations, yields and profits from no-till corn production are similar to or exceed those of conventional tillage. Reduced soil erosion has always been a convincing argument for no-till production. Yet some management problems persist, limiting acceptance of the practice. The broad spectrum of herbicides now available has eased some of the challenging weed control problems in no-till. Research has also identified solutions to potential problems related to no-till nitrogen management.

The soil environment in a non-tilled soil is vastly different from that of a clean-tilled field. Previous crop residues left on the soil surface are one obvious difference affecting many other soil properties and processes. One difference is the effect on soil nitrogen. This publication discusses the effects of surface residues on soil nitrogen and methods of managing fertilizer nitrogen to improve the efficiency of its use in a no-till cropping system. The focus is on corn production; however, many of the management practices can be applied to grain sorghum, wheat or other crops requiring nitrogen in no-till systems.

Nitrogen changes in no-till systems

Without annual mixing of the soil and crop residue by tillage, no-till systems accumulate a layer of crop residues on the soil surface. This residue layer may depress grain yields because of its negative effects on surface-applied nitrogen.

The nitrogen cycle is a complex process. Nitrogen is cycled through mineralization (release) and immobilization (tie-up).

The availability of nitrogen to crops is affected by surface crop residues. Nitrogen in the organic form is unavailable to crops. Nitrogen in the inorganic form (nitrate and ammonium) is available to growing crops. The surface residue in no-till systems may result in significant immobilization of surface-applied nitrogen. When nitrogen fertilizer is applied as urea, the nitrogen may also be lost by escaping as a gas into the atmosphere. This loss is indirectly related to surface crop residues.

The availability of fertilizer nitrogen for crops also depends on the amount immobilized by soil microbes. Soil microbe populations tend to increase with surface residue. Since no-till systems have greater amounts of surface residue than clean tillage, they also have a greater potential for nitrogen immobilization. Immobilized nitrogen is not lost from the soil. It is just temporarily unavailable. Immobilized nitrogen must be mineralized to be made available to a growing crop. The lack of soil mixing with no-till results in a relatively slow mineralization of nitrogen from the crop residues. Alternatively, plowing a soil mixes the residue with the soil. Soil microbes can then decompose the residue more rapidly and mineralize nitrogen in the residue.

Soils in no-till systems tend to be more moist than plowed soils. Soil moisture ultimately affects nitrogen management. A layer of crop residues on the soil surface reduces evaporation from the soil surface. Alternatively, tillage promotes evaporation and dries out soil to the depth of tillage. A wetter soil also tends to be a cooler soil. Thus, no-till soils tend to be wetter and cooler, so that they reduce microbial activity and the mineralization of crop residues and organic matter.

Denitrification is the microbiological conversion of nitrate nitrogen to nitrogen gas, which escapes into the air. Denitrification is caused by certain anaerobic bacteria. These bacteria are most active in low oxygen conditions. Since soil pores are filled with either water or air, increases in soil water result in decreased soil air and decreased soil oxygen. Compacted soils also have less air-filled pore space. No-till soils tend to be more compact and moister than plowed soils. Because of these conditions, no-till has increased populations of anaerobic bacteria, particularly in the upper 3 inches of soil. Imperfectly drained soils have greater potential for denitrification than well-drained soils. This can result in a greater nitrogen requirement for these soils when they are no-tilled rather than plowed.

Urea and urea-containing fertilizers (UAN solutions) are increasing in their share of fertilizer market sales. The high analysis of urea and the ease of handling of UAN solutions are reasons for their popularity. Yet both of these nitrogen sources have potential for greater nitrogen losses than other nitrogen sources. Applied to a field, urea is converted to ammonium carbonate by an enzyme found in soils called urease. Ammonium carbonate easily converts to ammonium and carbonate ions. The carbonate ions result in a relatively short-lived increase in soil pH around the fertilizer (granule, crystal or droplet). The ammonium ions at high pH convert to ammonia gas, which may escape into the air. This process is called volatilization.

The enzyme (urease) that breaks down urea is primarily found in crop residues. When urea or UAN solutions (50 percent urea-N) are broadcast-applied in no-till systems, the potential for volatilization is greatest with warm, moist soils and drying weather conditions. Moisture is necessary to start the hydrolysis reaction; the reaction rate increases with temperature. Drying of the soil surface promotes movement of ammonia away from the surface.

Volatilization can be greatly reduced or minimized by applying urea when soil temperatures are cool in the early spring. Alternatively, applying urea to the surface of dry soils also results in little volatilization. Volatilization can also be minimized by activities that move nitrogen into the soil, so that ammonia formed from urea hydrolysis can be attached to soil particles. These activities include: applying nitrogen just prior to a rain (of at least 0.4 inches), irrigating after fertilizer application and injecting the urea into the soil. Ammonium nitrate fertilizer is not subject to loss by the volatilization process.

When all factors with respect to nitrogen availability are considered, no-till behaves differently than clean-tilled systems. These factors result in a greater potential for nitrogen loss through immobilization, denitrification and ammonia volatilization.

Despite these problems, research at MU and elsewhere in the Midwest has identified productive and profitable nitrogen management practices for no-tillage corn production.

Nitrogen fertilizer sources and no-tillage

First time no-till farmers often tend to surface-broadcast nitrogen in no-till systems as they did in plowed systems. When urea or urea solutions are used, this can result in significant nitrogen losses and disappointing yields.

Data from a 3-year study in Missouri provide an estimate of nitrogen losses of surface-broadcast urea and UAN solution in a no-till system by comparing their performance to ammonium nitrate, which is not subject to ammonia volatilization (Table 1). Ammonium nitrate resulted in the highest yield. Urea produced the next highest yield, while two UAN solutions were lowest. The order of performance of the nitrogen sources was similar whether corn was grown following soybean or corn. The yield differences between nitrogen sources were largest when corn followed corn, suggesting a greater need for proper nitrogen management with this crop sequence.

Table 1
Nitrogen source effects on no-till corn yield in Missouri.*

Nitrogen source	Corn following soybean	Continuous corn
No nitrogen	109 bushels per acre	55 bushels per acre
Ammonium nitrate	158 bushels per acre	132 bushels per acre

Urea	149 bushels per acre	117 bushels per acre
UAN solution	144 bushels per acre	109 bushels per acre
UAN solution + ammonium thiosulfate	147 bushels per acre	114 bushels per acre

***Average of five site-years (1988 to 1990) and a nitrogen rate of 180 pounds nitrogen per acre.**

Ammonium thiosulfate has been shown to improve the performance of UAN solutions in some studies. In this study, however, its addition to UAN resulted in inconsistent and relatively small yield improvement.

Results from other studies in the Midwest also indicate that surface application of nitrogen sources that are not subject to ammonia volatilization losses, such as ammonium nitrate or ammonium sulfate, will outperform urea containing nitrogen sources.

Rainfall can play a role in the efficiency of urea that is broadcast-applied in no-till. Rainfall received soon after fertilizer application can move the fertilizer into the soil before significant volatilization losses can occur. Some studies have tried to characterize the amount of volatilization loss with the amount of time following fertilizer application until a rain. The study noted above indicated improved effectiveness of urea or UAN when applied just prior to a rain. However, the data did not suggest any predictive value in relating days until rain to urea performance.

Nitrogen placement and no-till corn production

Studies of nitrogen sources in no-till production clearly show a potential for large nitrogen losses or inefficiency with surface-applied nitrogen. Since much of the microbial activity and potential immobilization takes place near the soil surface in no-till production, placing nitrogen fertilizer below the soil surface should improve the efficiency and uptake of nitrogen in no-till. Interest has also been expressed in surface band applications (dribbled UAN solution) as a means of reducing fertilizer-residue contact. Surface-band application of nitrogen fertilizer may provide a means of improving nitrogen efficiency when injection of nitrogen fertilizer is not desirable or feasible.

Results from a 3-year study in Missouri showed increased yields when UAN was knife injected rather than surface applied (Table 2). Dribbled UAN resulted in only slightly greater yield than when broadcast. These Missouri results are similar to results of other studies conducted in the Midwest. This study also indicated that the relative performance of nitrogen placement methods did not vary between sidedress and preplant fertilizer applications.

Table 2
Yield of no-till corn in response to placement of UAN solution in Missouri.*

Nitrogen placement method	Applied at planting	Applied at sidedress
No nitrogen	75 bushels per acre	75 bushels per acre
Broadcast	120 bushels per acre	124 bushels per acre
Dribble	125 bushels per acre	125 bushels per acre
Knife injected	131 bushels per acre	135 bushels per acre

***Average of eight site-years (1987-1989) and a nitrogen rate of 180 pounds nitrogen per acre.**

Management of nitrogen in no-tillage corn production

The best management system for no-till offers the most consistent and highest nitrogen use efficiency. Conceptually, the best system would appear to be injection of nitrogen below the residue layer in the soil. Injection of anhydrous ammonia and liquid fertilizers should work equally well. Research in Missouri has shown this to be essentially true (Table 3).

Broadcast ammonium nitrate has also performed well. This study has also shown that surface broadcasting only a portion (50 pounds N per acre) of UAN and knife injecting the remainder can result in significant nitrogen loss and decreased yield.

Table 3
Nitrogen source and placement effects on no-till corn grain yield in Missouri.*

Nitrogen rate per acre	Broadcast ammonium nitrate	Anhydrous ammonia	Broadcast urea	Knife-injected UAN	Split-applied UAN
0 pounds			97		
100 pounds	155	141	137	130	127
150 pounds	160	163	149	156	134

***Average of two years (1991-1992) at three locations.**

Knife injection of anhydrous ammonia or UAN solution for no-till systems is best achieved with thin profile knives to minimize soil disturbance. Anhydrous ammonia should be injected deep enough to avoid "puffing." Slot closure and subsequent ammonia loss can be a problem when ammonia application is made to wet soils. Liquid or dry nitrogen sources can be knife injected at a shallow depth with no nitrogen loss. Most research involving knife-injected bands has used band spacings the width of the planned crop row. However, research in Missouri and Illinois has shown no yield loss with bands spaced every other row. Fertilizing every other row is best practiced as a sidedress application when crop rows can be seen and the bands can be precisely placed between the rows. Since the amount of material delivered to each band must be twice as great (to achieve an equal application rate), gaseous loss from the slot will be a greater concern when using anhydrous ammonia.

Just as knife-injecting UAN solution has been shown to increase yield, knife-injecting urea has also been shown to increase yield relative to surface-broadcast applications. Fertilizer equipment capable of injecting dry materials is available in some areas.

If surface-broadcast applications with no-till are necessary, ammonium nitrate should be the preferred nitrogen source. Urea should be considered a second choice. Yields comparable to those of other nitrogen sources or application methods can be achieved with urea by increasing the amount applied by 15 to 20 percent. However, this may not be a wise use of resources environmentally or economically. Fertilizer price and availability of other nitrogen sources or application methods should dictate the decision to surface-broadcast urea. Surface-broadcast applications of UAN are not recommended.

Nitrogen rates recommended by a soil test may need to be altered from those of conventional tillage even if ammonium nitrate or injected nitrogen is used. Soil drainage and crop rotation are factors to consider when deciding on a recommended rate of nitrogen for no-till. Crops grown no-till on well-drained soils may have increased yields because of the additional soil moisture retained by the crop residue. On such soils, nitrogen requirements may be increased 10 to 15 percent. No-till nitrogen recommendations should be similar to conventional tillage systems when expected yields are similar.

Imperfectly drained soils cropped no-till have increased potential for denitrification. The high residue levels of no-till continuous corn on imperfectly drained soils can result in much nitrogen loss. Research in Missouri has indicated that reduced yields can be expected with continuous no-till corn on these soils. Reduced yields require less nitrogen, so nitrogen recommendations should reflect the yield level. No-till corn following soybeans should yield similarly to conventional tillage systems. However, nitrogen recommendations should be increased by 10 to 20 percent.

The timing of nitrogen applications for no-till systems should be the same as conventional tillage systems. Fall application is more risky and should be done only on soils with a very low potential for waterlogging or leaching conditions in the winter or spring, or it must include a nitrification inhibitor. Delay fall application of nitrogen until soils are near or below 50 degrees Fahrenheit at a 4-inch depth. The date at which this occurs is usually mid to late November in central Missouri. Ammonium forms of nitrogen are always the preferred source for fall application.

The original author for this publication was Daryl D. Buchholz, former faculty member of the MU Department of Agronomy. The authors wish to thank Dr. J.R. Brown and Dr. H.C. Minor for reviewing and making suggestions for this publication.

Related MU Extension publications

- G9176, Fertilizer Management for No-Till Corn and Grain Sorghum in Missouri
  http://extension.missouri.edu/p/G9176
- IPM1027, Best Management Practices for Nitrogen Fertilizer in Missouri
  http://extension.missouri.edu/p/IPM1027
- M164, Missouri No-Till Planting Systems
  http://extension.missouri.edu/p/M164

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