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Managing Nitrogen Fertilizers for Maximum Efficiency in Reduced Tillage Systems

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Soil erosion is a major problem facing farmers in many areas of the U.S. today. One practice which has demonstrated marked success at controlling erosion is conservation tillage. Reducing tillage and leaving a protective cover of crop residue does reduce erosion. However, in many situations, the practice can also lead to reduced uptake efficiency of nitrogen fertilizers. The objectives of this publication are 1) to describe some of the features of conservation tillage that can influence N use efficiency, 2) to explain the results of some recent research in the area, and 3) to outline alternatives for developing effective and efficient N fertilization programs for corn under different tillage systems.

NITROGEN EFFICIENCY UNDER CONSERVATION TILLAGE

In general, conservation tillage involves less mixing of the soil than conventional tillage systems and leaves more crop residues on the surface to serve as a protective mulch. However, the degree of mixing and residue incorporation varies greatly with the system used. Researchers in Indiana measured the percent of the soil surface covered by residue immediately after planting under a number of tillage systems. Their results (Figure 1) show residue cover ranging from less than 1 percent for moldboard plowing to over 90 percent for no-till. Chisel plowing, while considered a conservation tillage system, only left from 6 to 29 percent of the surface residue covered, depending on the type of residue being tilled (cornstalks, bean stubble, etc.) and the type of chisel being used.

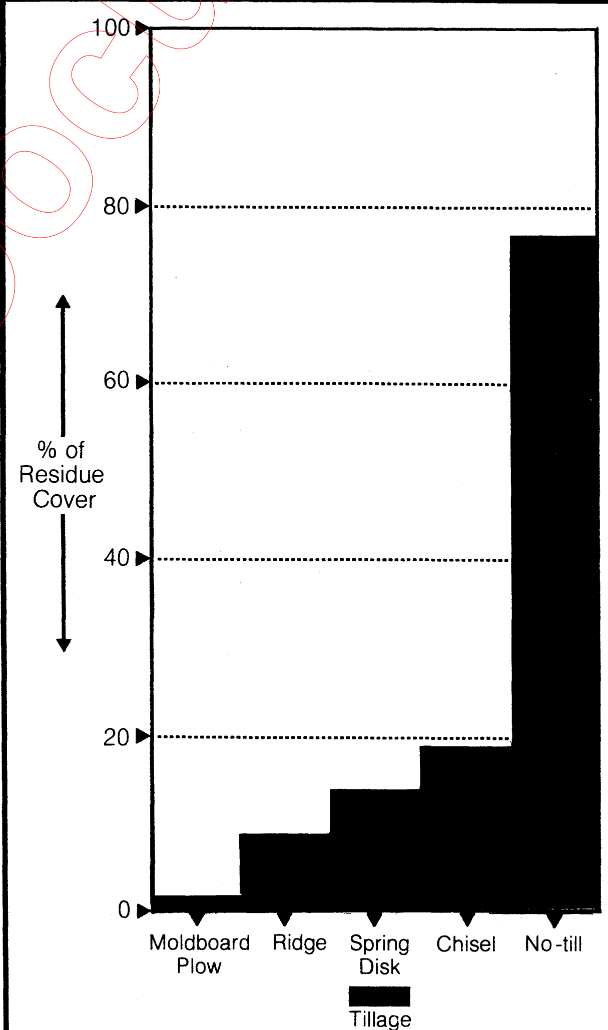

Figure 1. Tillage System Used and Percentage of Residue Cover After Planting.

Increased Residue Cover

The amount of residue left on the surface after tillage has a significant effect on the use efficiency of nitrogen fertilizer, particularly when fertilizer is applied directly to the residue. This was confirmed by two studies undertaken in Indiana. In the first, using continuous corn under several different tillage systems, nitrogen was either broadcast on the surface immediately after planting or knifed 6 inches deep between the rows before planting. The results (Table 1) clearly show that the effectiveness of surface-applied N decreases as residue levels increase. The second study was conducted with a number of nitrogen sources and placement methods under spring plowing and no-till, and it illustrates a similar trend (Table 2). Both studies confirm that under clean tillage little or no difference can be noted between nitrogen sources and application systems. However, when nitrogen fertilizer is placed in direct contact with surface residue in no-till systems, yield results are generally not as good as when N is placed below the residue.

Soil Changes

The protective cover of crop residue left under conservation tillage causes a number of changes to occur in soil which also affect nitrogen fertilizer efficiency. The surface cover reduces runoff, increases infiltration, and reduces evaporation, all factors leading to higher soil moisture contents under no-till. This can lead to greater leaching losses of nitrogen.

Changes in microbial populations have also been found to be associated with a surface residue layer. Increases have been found in the populations of bacteria responsible for both nitrification (the conversion of ammonium N to nitrate N) and denitrification (the conversion of nitrate N to N2 gas) when the soil surface is covered with a residue mulch. This suggests that nitrogen transformations can occur more quickly in reduced tillage systems. This finding also suggests that a greater potential for nitrogen immobilization might also exist in surface mulch.

Nitrogen immobilization is the incorporation of N into soil organic matter. The more nitrogen that is immobilized, the less there is available for the growing crop. One study found that immobilization was almost doubled in no-till. The same study also found a strong positive correlation between the amount of N immobilized and the organic carbon content of the surface 2 inches of soil.

Table 1. Effect of nitrogen placement on corn yield in three tillage systems. Pinney Purdue Ag Center, 1971-73.

Nitrogen placement	Plow	Chisel	No-till
		bu./a.	
Broadcast	136	131	121
Injected	136	140	137
	NS	NS	—

Source: Griffith and Mannering, IN.

Besides the potential for increased leaching, denitrification, and increased immobilization, the possibility of ammonia volatilization also exists. In simplest terms, ammonia volatilization is the loss of ammonia gas from the soil surface to the atmosphere. Applying urea or urea containing fertilizers such as urea-ammonium nitrate solutions (UAN) to the surface of residue covered soil can result in significant N loss. As much as a third of surface-applied urea has been shown to be lost in a no-till corn field. Losses from surface-applied UAN have been found to be about one sixth of the applied N.

Nitrogen Sources

In Maryland, research has also been conducted on the influence of nitrogen source on N use efficiency in no-till systems. The study in question considered ammonium nitrate,

Table 2. Effect of nitrogen source and placement on corn yield, leaf N concentration and grain N concentration in both plow and no-till production systems. Southeast Purdue Ag Center, 1982.

	Plow			No-till		
Nitrogen source and placement	Yield bu./a.	Ear leaf % N	Grain % N	Yield bu./a.	Ear leaf % N	Grain % N
UAN Broadcast-not incorp.	145	2.48	1.21	128	1.63	1.08
UAN Broadcast-incorp.	153	2.34	1.23	—	—	—
UAN Injected	149	2.44	1.29	156	2.13	0.94
LSD .05	NS	NS	NS	23	0.27	0.17

Source: Mengel, IN.

urea, and UAN solutions, all surface-applied. In all cases where significant differences were observed between sources, little if any rainfall occurred in the first few days after N application. This is a point noted by all researchers working with N management and tillage systems. If significant rainfall occurs shortly after N application, no real performance difference is noted between commonly used surface-applied N sources. However, if dry weather prevails, urea or urea-containing materials appear to be a problem. In the Maryland study (Table 3), highest yields were obtained with ammonium nitrate, intermediate with UAN, and lowest with urea.

Table 3. Influence of nitrogen source on grain yield of no-till corn in Maryland.

N source used	No-till corn yield bu./a.
No N check	90
Ammonium Nitrate	127
Urea Prilled	117
Urea Granules	119
UAN Solutions	123

Source: Bandel et. al., MD. (*Agronomy Journal* 72:337-340, 1980).

Similar findings come from Pennsylvania, where ammonium sulfate and ammonium nitrate both performed better than urea and UAN. Total N uptake was also highest with ammonium nitrate and ammonium sulfate and lowest with urea and UAN.

The Pennsylvania study also measured the effect of different N sources on soil pH after 5 years of continuous applications. The results showed little difference in the effects of ammonium nitrate, urea, or UAN on lowering soil pH. But ammonium sulfate applications for 5 years resulted in a pH of 4.7 in the top inch of soil where 180 pounds of N per acre had been applied. This points out the need to closely monitor the pH of soil when the N source is applied on the surface, especially when ammonium sulfate is used.

Nitrogen Placement

The lack of performance of surface-applied N fertilizers in Indiana tillage experiments led the Purdue tillage research team to adapt an anhydrous ammonia applicator to no-till by mounting a coulter ahead of the knife to cut through the residue and welding an additional sealing wing on the knife to close the slot. This system has been routinely used since 1975 in Purdue tillage work.

Beginning in 1978, a series of experiments were conducted to study the relative advantage of injecting anhydrous ammonia or UAN in no-till as compared to surface applications of urea or UAN. The results of these experiments (Table 4) show a clear advantage of injection of anhydrous ammonia or UAN over surface application of these substances. Injection treatments averaged 137 bushels per acre as opposed to surface-applied treatments, which averaged 121 bushels per acre. All plots received 150 pounds N per acre. These findings have been supported by other studies.

Table 4. Effect of N source and placement on no-till corn yield and ear leaf N in seven experiments conducted from 1978 through 1980. Indiana.

Nitrogen treatment	Grain yield bu./a.	Ear leaf N % N
NH_3 Injected	139	3.06
UAN Injected	135	2.85
UAN Surface	118	2.48
Urea Surface	123	2.57

Source: Mengel, Nelson, and Huber, IN.

Recently research in Alabama has focused on the concept of surface banding or "dribble" applications. The results of the banding experiments (Table 5) show that surface banding of

Table 5. No-till corn yield as affected by method of application and N rate with UAN. Alabama, Touchton and Hargrove, 1982.

	1979			1980		
N rate	Band incorp.	Band surface	Spray	Band incorp.	Band surface	Spray
lbs./a.		bu./a.			bu./a.	
80	136	120	80	115	116	99
160	163	147	101	119	119	115
240	158	157	114	112	120	115

Source: Touchton and Hargrave, GA. (*Agronomy Journal* 74:823-826, 1982).

UAN offers a method for reducing N losses without the additional expense of incorporation or injection. While the efficiency of the surface band at low rates was not as good as that obtained with incorporation, it was better than surface broadcasting. Similar experiments in Maryland showed a response to dribble or surface banding close to that obtained with injection. Thus surface banding may well offer a reasonable alternative to those farmers who are unwilling to inject or who wish to use custom application, for which surface banding is ideally suited.

MANAGEMENT ALTERNATIVES

After reviewing all of this information, what alternatives should a farmer consider when developing a nitrogen management program for no-till corn?

The research clearly shows that the preferred system is the injection of N below the residue. Injection affords more assurance that the applied N will be utilized by the crop, and it removes the variable of weather. N sources such as anhydrous ammonia and UAN solutions are well suited for this type of program.

In the event a farmer is unable to adapt injection procedures, then surface banding may afford some enhancement of performance over broadcasting urea or spraying UAN in the more traditional manner. However, to date, the results have not shown surface banding to be as efficient or as consistent as injection. Thus it must be viewed as a compromise, not as good as injection, but better than broadcasting solids or solutions.

In straight broadcast situations, ammonium nitrate is presently the preferred N source in most cases. This is primarily due to the fact that it is a non-volatile N source and that granular materials appear to be slightly less prone to immobilization problems than solutions. Ammonium sulfate would also fit in at this point; however, the higher acidity resulting from ammonium sulfate application could present problems if not corrected. Thus, for this reason alone, using ammonium sulfate as a primary N source in no-till is not recommended.

UAN solutions sprayed on the surface, probably the most common system used today, is next in preference. UAN broadcast can have a definite problem under some situations, but this is probably preferrable to urea solids, last on the list of alternatives.

In Indiana, the ability to combine trips through "weed and feed" operations can result in important time savings, and this makes N solutions very attractive. In these situations it is recommended that farmers increase their N rate 15-30 percent to attempt to compensate for the efficiency problem and take advantage of the timeliness of combining trips or, in many instances, custom application.

The recommendations listed above may well be obsolete in a relatively short period of time as researchers continue to work in the area and new technology comes on stream. Among the promising possibilities are new, lower power subsurface-placement techniques, urease inhibition with urea to minimize volatilization, and a host of timing- and split-application techniques. However, the nitrogen management alternatives outlined in this publication will enable the farmer to minimize nitrogen loss problems while still taking advantage of the erosion control offered by conservation tillage.

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