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## EC96-144 Fertilizer Management for Conservation Tillage

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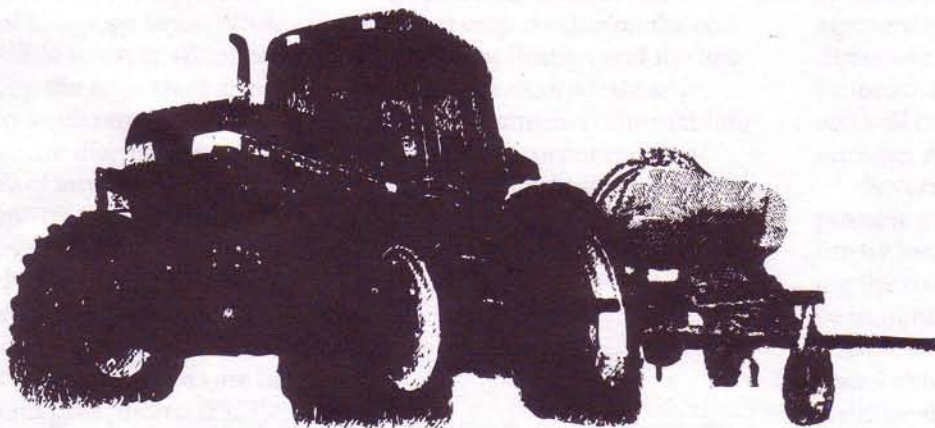
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# Fertilizer Management



# for Conservation Tillage



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# Fertilizer Management for Conservation Tillage

Charles A. Shapiro and Richard B. Ferguson

*Conservation tillage as a means of reducing soil erosion has increased in popularity due to government conservation compliance and economic factors. Management of crops under reduced tillage has necessitated changes in the use of several inputs. The goal of this publication is to focus on the use of fertilizers under reduced tillage with special emphasis on corn production practices.*

How does fertilizer management differ in conservation tillage compared to conventional tillage? The answer is based on the fundamentals of managing soil fertility. Fertilizer principles are the same regardless of tillage systems. While it is not possible to cover all aspects of soil fertility, the important areas that relate to fertilization in conservation tillage are discussed here.

The goal of any fertilizer program is to ensure that proper nutrients are present in the root zone and available when the plant needs them. In Nebraska, the two nutrients that are used the most and have the greatest impact on yields are nitrogen (N) and phosphorus (P). Since nitrogen is a mobile nutrient and phosphorus a non-mobile nutrient, these nutrients must be managed differently in a conservation tillage system. Mobile nutrients will move easily in the soil solution and can be expected to move away from the point of application. Non-mobile nutrients move very slowly and must be placed near roots or where roots are expected to grow.

A sound fertilizer program is based on soil testing regardless of tillage regime. Soil tests identify deficiencies and help suggest proper application rates. Producers who do not know the fertility levels of their fields are destined to either have yield reductions or over-application of fertilizer. Both situations will increase cost of production and reduce the producer's ability to

compete in the marketplace. Specific fertilizer recommendations are given in various NebGuides and will not be discussed here.

The unique problems reduced tillage presents relate to the increased crop residue on the soil surface at application and the limited ability to incorporate any broadcast treatments. The inability to uniformly incorporate phosphorus in reduced tillage presents a challenge when taking a soil sample. We will discuss strategies to manage these problems.

## Nitrogen

Probably the most frequently asked question is "Do nitrogen rates go up under no-till?" The answer depends on how and when nitrogen is supplied to the root-zone. To successfully apply the correct amount of nitrogen you need to understand the nitrogen cycle.

While it may seem academic to study the nitrogen cycle, (Figure 1), with an understanding of the processes controlling the form of nitrogen in the field, the producer will be able to make the management adjustments necessary to produce crops efficiently. Nitrogen is a unique essential plant nutrient that can exist in several forms at the same time and goes through many changes in the soil. Processes that influence gains and losses of nitrogen include nitrification, ammonia

volatilization, immobilization, denitrification, symbiotic fixation, mineralization, and leaching. Each of these processes go on continually in the soil. Only the processes that are most important to nitrogen management in reduced tillage will be discussed here. Understanding the factors that control nitrogen in the soil will help the producer manage nitrogen more effectively.

Several of these processes are possible pathways where nitrogen can be lost or prevented from reaching the roots. If nitrogen losses can be minimized or prevented then the answer to the question about rates, posed above is, "No, for a given yield level nitrogen rates are the same for conservation tillage as for conventional tillage."

## Fall Nitrogen Applications

Fall applied anhydrous ammonia will be converted from ammonia ( $\text{NH}_3$ ) to nitrate ( $\text{NO}_3^-$ ) through a process called **nitrification** (#1 in Figure 1). The ammonium ion ( $\text{NH}_4^+$ ) has a positive charge that can attach to negatively charged soil and organic matter particles. However, once the  $\text{NH}_4^+$  is converted to  $\text{NO}_3^-$  then the nitrogen is subject to leaching (#7 in Figure 1). Nitrate dissolves in water and moves with water in soil.

Nitrification is a bacterial process, and the rate of conversion from ammonium to nitrate is primarily



# The Nitrogen Cycle

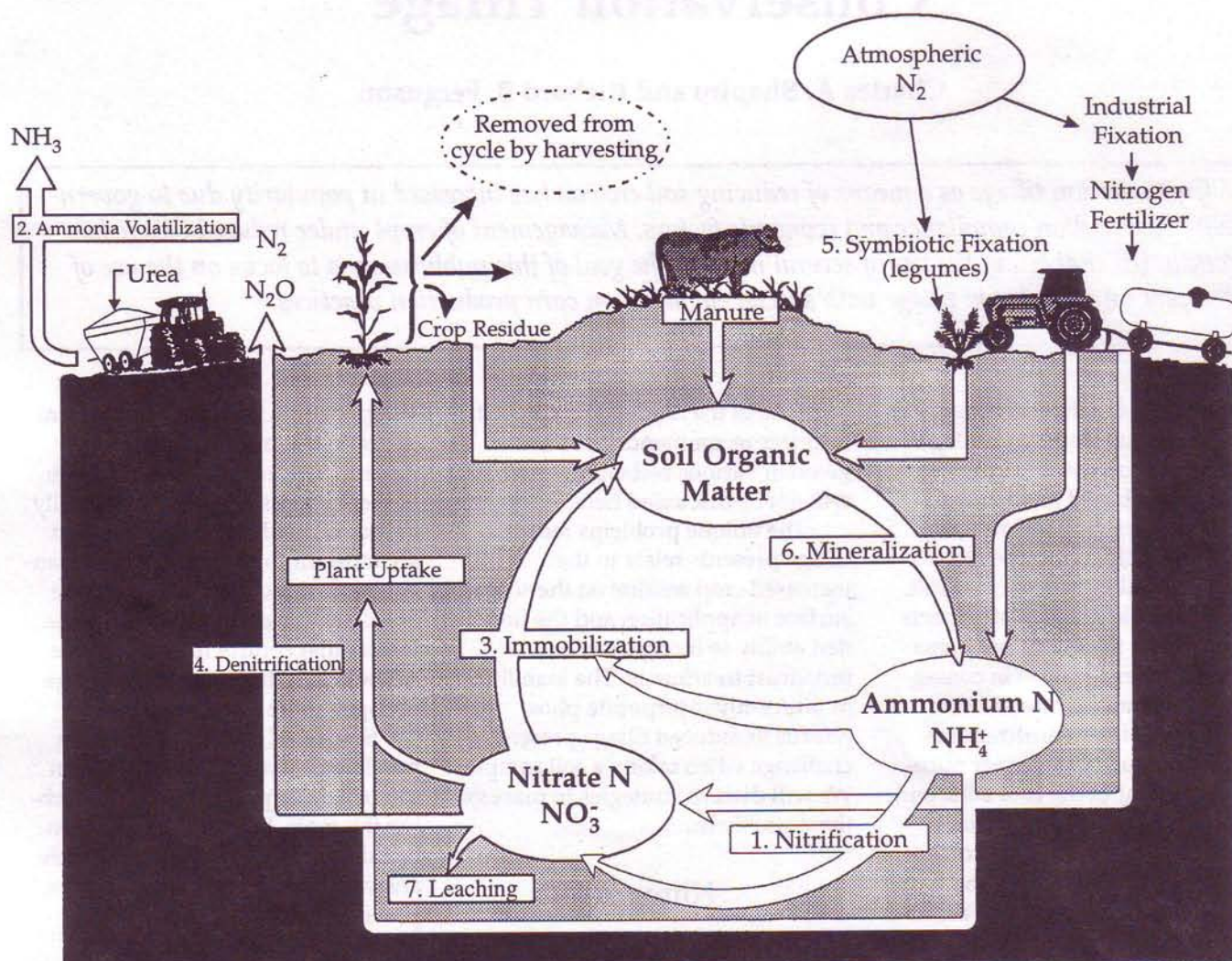


Figure 1. The Nitrogen Cycle (After Bundy, 1985)

regulated by temperature (Figure 2). The rate of change is fastest at high temperatures. When the temperature is near 80°F complete conversion from ammonium to nitrate will take place in two weeks. Fall applied anhydrous ammonia into soils that stay below 50° will remain primarily in the  $NH_4^+$  form until the spring thaw. It is possible to use a nitrification inhibitor to suppress bacterial populations that make the conversion. Products such as nitrapyrin (N-Serve®)<sup>1</sup>, and dicyandiamide (DCD) - (Guardian®<sup>1</sup>, Blue

Max®<sup>1</sup>) are nitrification inhibitors that act to temporarily suppress populations of *Nitrosomonas* and *Nitrosococcus* bacteria that transform ammonium to nitrate. These chemicals are effective in slowing the nitrification process, but will they increase yields or stop leaching? Nitrapyrin effectiveness is short lived. Spring applied nitrapyrin may be effective for three to six weeks. Temperature influences the rate at which nitrification inhibitors break down, similar to the way temperature affects nitrification.

Theoretically, using a nitrification inhibitor will allow anhydrous ammonia application to begin earlier in the fall since nitrification will be delayed until soils begin to warm up in the spring. Keeping the anhydrous ammonia in the ammonia form will prevent leaching. Nitrate based fertilizers should not be applied in the fall since they can leach.

If fall applied ammonia nitrogen does convert to nitrate, then a winter or spring with heavy rains will leach nitrogen (see #7 in Figure 1).

<sup>1</sup>®Disclaimer and trademark. Reference to commercial products or trade names is made with the understanding that no discrimination is intended and no endorsement by Cooperative Extension is implied.



Whether it is leached below the root zone depends on how much rain falls and the drainage characteristics of the soil. Since nitrate is soluble in water, water moving below the root zone will carry nitrate with it.

The rate at which spring applied ammonia will convert to nitrate is also regulated by soil temperature (Figure 2). However, the potential for nitrate leaching from spring applied ammonia is less than with fall applied N for several reasons. Soil temperatures are often quite cool in the spring, slowing nitrification. Compared to application in the fall, the time between spring application and crop uptake of N is much shorter.

## Broadcast N Applications

Potential loss of broadcast applications of urea and urea based fertilizer are of most concern to those practicing conservation tillage. Urea is inexpensive and besides being available as a dry product, it is a major component of the liquid nitrogen product known as UAN (Urea-Ammonium Nitrate). Urea can be lost through the process of **ammonia volatilization** (#2 in Figure 1). The enzyme urease is present in both soil and plant residues. Urease splits the urea molecule producing ammonium and carbon dioxide. Water is needed for the reaction to occur. If

the soil surface is dry the conversion won't take place. In addition, pH effects the relative proportion of ammonia ( $\text{NH}_3$ ) and ammonium ( $\text{NH}_4^+$ ) that is present. Ammonia is in greater proportion in higher pH soils. With high pH soils, the potential for gaseous nitrogen losses (Figure 3a) increases. Figure 3a shows the relationship of soil pH to ammonia loss and illustrates why some soils have greater gaseous nitrogen losses. Ammonia is lost as a gas while ammonium attaches to the soil.

These principles are important since broadcast nitrogen application is popular for conservation tillage either alone or in combination with

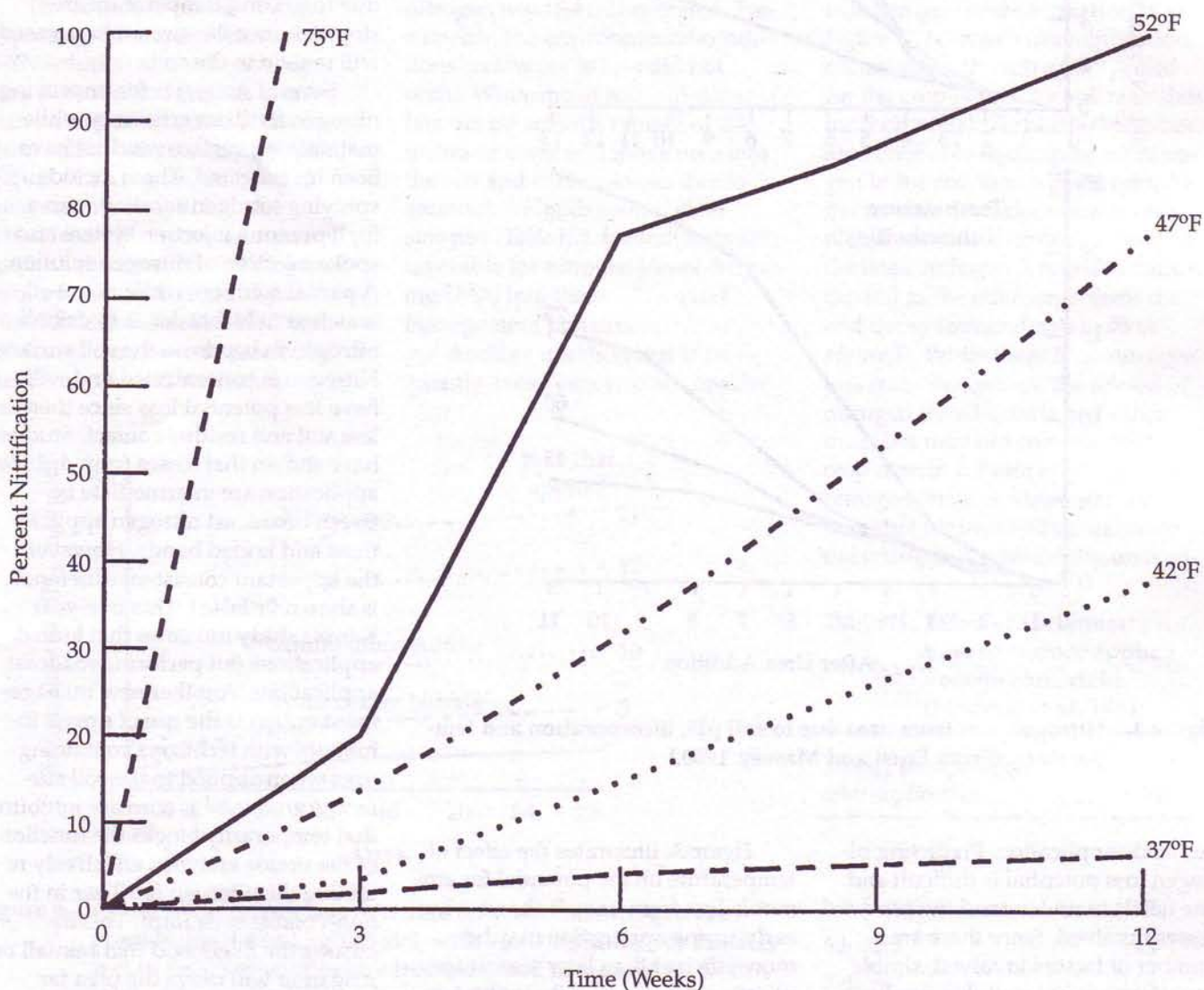


Figure 2. Effect of temperature on nitrification rate. (R. M. Thorup, 1984)



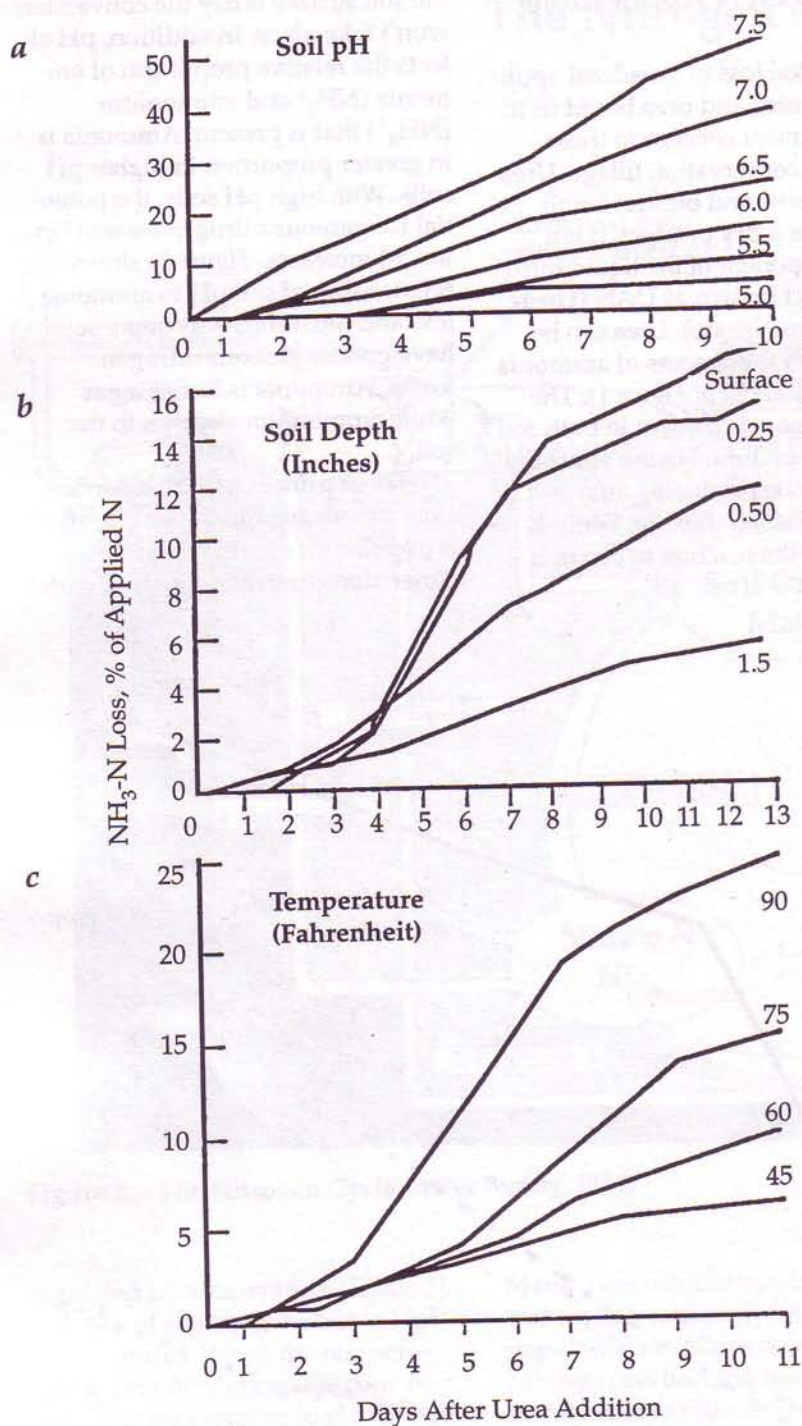


Figure 3. Nitrogen loss from urea due to soil pH, incorporation and temperature. (From Ernst and Massey, 1960.)

herbicide application. Predicting nitrogen loss potential is difficult and one needs to understand the processes involved. Since there are a number of factors involved, simple equations are not useful in predicting loss.

Figure 3c illustrates the effect of temperature on the potential for ammonia loss from urea. It shows why early spring application may be more efficient than later season application. Urease activity is also temperature dependent. Higher

temperatures increase the rate of ammonia loss. In the study quoted in Figure 3, 10 percent of nitrogen was lost in 4, 8 and 11 days when soil temperatures were 90, 75, and 60° F, respectively. Urea applied in March or April may have less losses than urea applied in May or June. April soil temperatures are cooler than in May and have a higher probability of a significant rainfall event to move urea in the soil. Figure 3b shows decreased nitrogen loss due to incorporation. As depth of incorporation increases, nitrogen losses decrease. Figure 3 shows the value of knifed application methods compared to broadcast applications in reduced till since knifing places nitrogen underneath surface residue. Once urea is incorporated, the loss due to pH and temperature are stopped since the ammonia released will remain in the soil.

Several strategies for improving nitrogen fertilizer efficiency while maintaining surface residues have been investigated. These include spraying nitrogen solution with a high pressure injection system and spoke injection of nitrogen solution. A partial solution, while not researched in Nebraska, is to dribble nitrogen in bands on the soil surface. Nitrogen is concentrated and will have less potential loss since there is less soil and residue contact. Studies have shown that losses from dribble application are intermediate between broadcast nitrogen applications and knifed bands. However, the important consistent difference is shown in Table I. This five-year Kansas study indicates that knifed applications out perform broadcast applications. Another new management option is the use of urease inhibitors with fertilizers containing urea when applied to the soil surface. Agrotain®<sup>1</sup> is a urease inhibitor that temporarily blocks the function of the urease enzyme, effectively retaining the nitrogen fertilizer in the non-volatile urea form. This increases the likelihood that rainfall or irrigation will move the urea far enough into the soil that ammonia volatilization is no longer a concern.



**Table I. Effect of application method on corn grain yield, 1987-1991 (averaged over nitrogen rates). (Gordon et al. 1993)**

	1987	1988	1989	1990	1991	Avg
	-----Bu/ Acre-----					
No nitrogen check	112	70	79	116	91	94
<b>Application Method</b>						
AA; Preplant, Knife	154	151	165	169	144	157 A
UAN; Preplant, Knife	158	151	165	169	144	157 A
UAN; Preplant, B'st	130	137	152	168	130	143 C
UAN; Preplant, Dribble	135	143	159	157	128	145 C
UAN; Split, Knife	157	146	167	165	140	155 A
UAN; Split, Dribble	151	140	156	163	141	150 B
	*	*	*	NS	*	

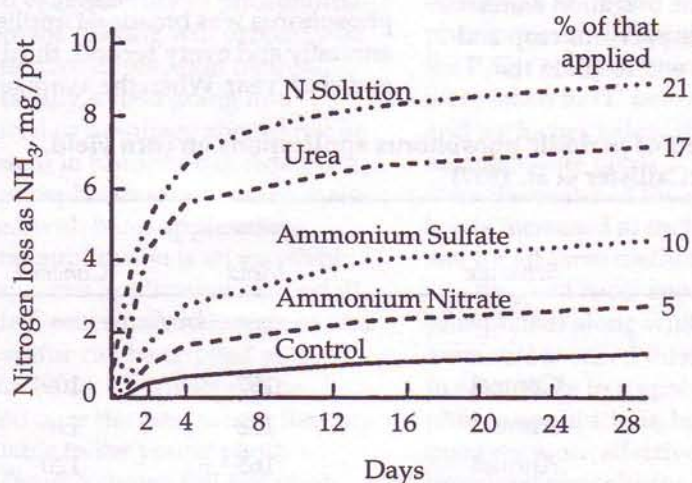
The source of nitrogen is also important. Research verifies that UAN solution and urea usually have potential for greater losses than ammonium nitrate and ammonium sulfate when surface applied (Figure 4). But again, soil and climate conditions will influence actual loss. Nitrogen losses do not occur all the time. Table II shows results from another multi-year study conducted in Kansas. Nitrogen losses may have occurred, but there was no yield reduction when

nitrogen was not incorporated. Presumably, the environmental conditions conducive to loss did not occur. While moist soil will stimulate urease activity, rainfall of 0.4 inches or more will move urea into the soil and surface losses due to ammonia volatilization will be stopped (Table III). If conditions are favorable for nitrogen losses, irrigating UAN into the soil is a valid management practice.

Another question that is frequently asked concerns the relative

losses between broadcast urea and UAN solution. In one Kansas study, ammonia loss from bare soil and wheat stubble was compared. Using applications of solution UAN and dry urea. The ammonia in the UAN solution was lost quickly on the high pH wheat straw. Apparently, UAN was retained on the straw and urease activity was greater on the residue than on bare soil. Urea granules that fell through the residue to the soil surface hydrolyzed (decomposed) more slowly, and consequently were less subject to ammonia volatilization. In the laboratory study shown in Figure 4, the UAN solution also had slightly higher losses than urea.

An additional concern with surface application is the potential for soil nitrogen immobilization (#3 in Figure 1). Nitrogen immobilization occurs when the nitrogen applied for the crop is used by soil microbes for their metabolic needs. Microbes are better able to compete for nitrogen in the soil than a plant root. As the residue decomposition is completed and the microbial population declines, nitrogen is released back to the soil as the microorganisms die and decay (mineralization #6 in Figure 1). While there is no nitrogen loss from the system, the release of nitrogen from bacteria and other microbes may not coincide with crop demand. Knife application of nitrogen fertilizer decreases the potential for immobilization since the nitrogen is positionally unavailable



**Figure 4. Ammonia nitrogen loss overtime from several nitrogen compounds. (Soil was Crofton silt. with straw residue over surface, wet to field capacity before treatment and incubated at 75° F. A total of 36 mg. Fertilizer nitrogen added per pot, equivalent to 100 lb nitrogen/acre. Meyer et al. 1961.)**

**Table II. Effect of incorporation time of surface applied urea on corn yield. (Maddux et al. 1984)**

Time of incorporation after application	Corn Yield
	bu/a
No fertilizer	87
8 hours	143
7 days	146
Not incorporated	145



**Table III. Rainfall amount effect on nitrogen loss from surface applied urea. (Fox and Hoffman, 1981)**

<i>Rainfall</i>	<i>Time after rainfall</i>	<i>Loss</i>
inches / acre	days	percent
0.4	2	0
0.4	3	<10
0.25	5	10-30
0	6	>30

able for microbes but positionally available for plant needs. This is because microbes are mostly near the soil surface and decrease with depth.

### Recommendations

There is no ideal fertilizing scheme for nitrogen; our recommendation for most situations is to ensure enough early nitrogen to sustain the plant for the first three to six weeks. About 30-50 pounds of nitrogen per acre should be sufficient. Early season nitrogen can be applied in the starter, as a band above the seed, or along with a herbicide (weed and feed). Early season nitrogen is especially important on coarse textured soils and in years when off-season rainfall may have moved soil nitrate below the top six inches. Because of potential volatilization losses, weed and feed application of nitrogen may be subject to more nitrogen loss than a true starter application.

### Nitrogen Application Recommendations

If the conservation plan allows for knife application into residue, preplant anhydrous ammonia is an inexpensive nitrogen source. If early season anhydrous ammonia application is not possible, sidedress knife applications or surface banded nitrogen with incorporation by cultivation is acceptable. Another inexpensive and time-saving method is to use a spinner spreader to apply

dry nitrogen before cultivation. These methods are very efficient if one is planning on cultivating anyway. The important principle is not to leave a large quantity of nitrogen on the surface for an extended time period. If surface applying nitrogen fertilizer, avoid high pH soil, moist soil and warm periods whenever possible. If nitrogen deficiencies are detected during the growing season then more nitrogen should be applied.

### Nitrogen Summary

The initial point of discussion was whether nitrogen rates need to be different under reduced tillage. The University of Nebraska Nitrogen Best Management procedures of allowing various credits for nitrogen from soil nitrate, irrigation water nitrate, manure, previous crop and organic matter will result in the

same nitrogen rate recommendation regardless of tillage when the yield goal remains the same. It is essential that this nitrogen be managed to minimize loss so maximum profit results. Losses from the various pathways discussed above will necessitate re-examining total nitrogen needs and may mean additional nitrogen application is justified. The preferable alternative is to manage fertilizer nitrogen so that losses are avoided.

### Phosphorus

Phosphorus (P) is easier to discuss since there are fewer management options, but with fewer management options, phosphorus may be more difficult to manage. Since many soils may be high in soil phosphorus it is important to have a recent soil test. Phosphorus is not mobile, so there is less concern about leaching losses. On sloping land, erosion may move phosphorus offsite. However, since phosphorus is relatively immobile in the soil, management for crop production needs to focus on placement.

On many Nebraska soils, phosphorus can be applied in large enough quantities to be sufficient for more than one year. In corn studies at two sites in Nebraska (Table IV), phosphorus was broadcast applied annually and every second, third and sixth year. When the average

**Table IV. Effect of periodic phosphorus applications on corn yield. (McCallister et al. 1987)**

<i>Treatment</i>			
$P_2O_5$	<i>Schedule</i>	<i>Mead</i>	<i>Concord</i>
lbs/acre		-----bu/acre-----	
0	Control	157	109
24	Annual	158	116
48	Annual	165	120
72	Annual	164	118
48	Every 2nd yr.	158	113
72	Every 3rd yr.	163	115
144	Every 2nd yr.	161	118
144	Every 6th yr.	155	116



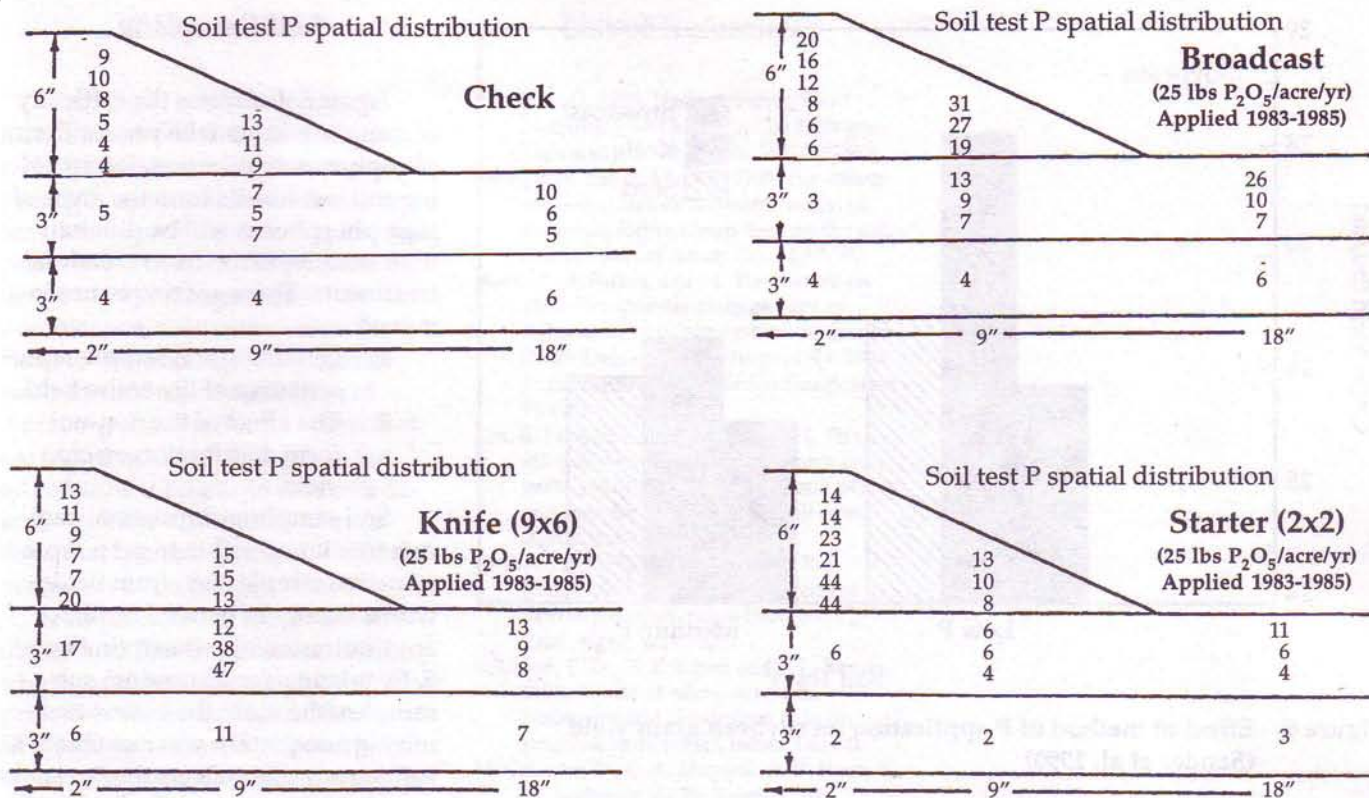


Figure 5. Phosphorus buildup from various application methods in ridge till. (Fixen et al. 1985)

annual rates were similar the periodic applications yielded almost as well as the annual applications. One implication of this finding is that if the conservation program allows one disking every other year in a corn-soybean rotation then applying a two year quantity of phosphorus before the disking will probably be an effective application method.

Ideally, a field going into reduced or no-tillage should not be deficient in phosphorus. Adequate soil phosphorus levels can be maintained with band applications. Starter application is an excellent phosphorus application method. If needed, other nutrients such as zinc and sulfur can be applied in the starter band. Nutrients can be placed near the seed where they are available to the young plant.

Figure 5 shows soil test phosphorus build-up of phosphorus levels over time with different application methods in a ridge-till system. This experiment was conducted in South Dakota and shows that phosphorus does not move very

far in soil. In this study, there were no significant yield effects among application methods. Corn was able to utilize the phosphorus regardless of where it was placed in the soil. Figure 5 shows the soil test phosphorus levels in the soil for the check, broadcast, knife and starter phosphorus treatment applications of 25 lbs  $P_2O_5$ /acre per year. Soil samples were taken to 11" below the ridge and six inches below the furrow. Soil samples were taken 2", 9", and 18" from the center of the ridge. Soil test levels increased at the application site for all three methods.

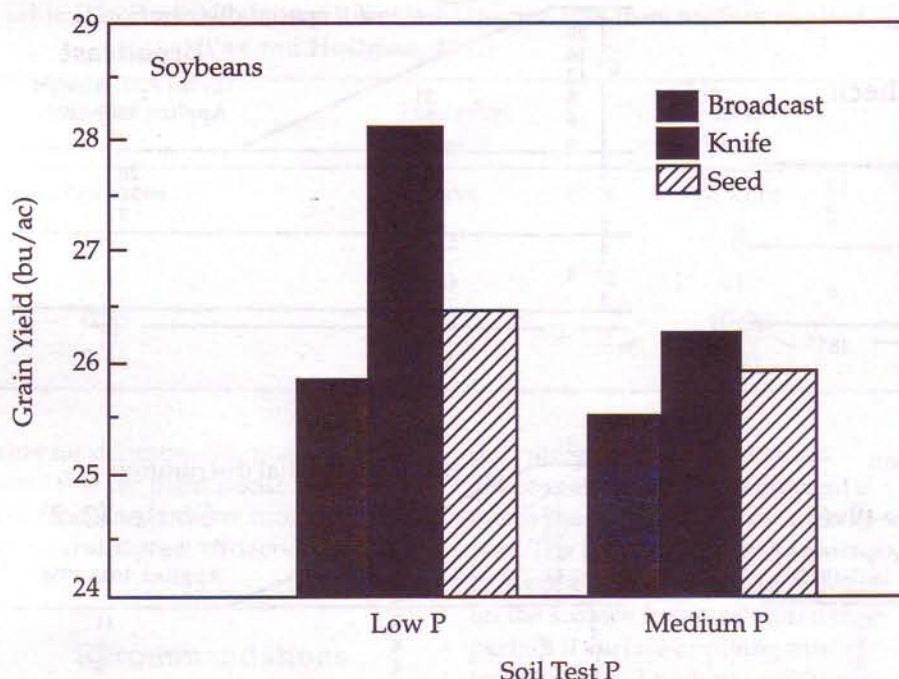
Preplant band application of phosphorus along with anhydrous ammonia is called dual placement. In soils likely to respond to phosphorus applications, band applications are more effective than broadcast phosphorus applications, unless the soil phosphorus level is very low. When the Bray-1 soil test is under 5 ppm, application with both a band and broadcast phosphorus application may increase yields more effectively than either alone.

Band applications create a continuous zone of enriched phosphorus concentration. Once a root intercepts an area of high phosphorus concentration it will continually grow in the band and take phosphorus up to satisfy the plants needs.

The benefit of banding seems to be true for soybeans as well as corn. On low testing phosphorus soils, knife applied phosphorus increases yields above broadcast applications (Figure 6). On average, a two-bushel yield increase was achieved over eight locations.

Some Nebraska data collected under irrigated, reduced-tillage situations show broadcast phosphorus applications may compare favorably to band applications. Broadcast applications were effective because the surface stayed moist and root activity was greater near the surface than under conventional tillage. Until more research validates these findings broadcast phosphorus applications should be viewed as the method of last resort for conservation tillage systems.





**Figure 6.** Effect of method of P application on soybean grain yield. (Sander et al. 1990)

### Fertilizer Application Considerations

When possible, knife application is the preferred application method. Conservation considerations may not allow this option. In addition, on steep slopes knifing up and down hills is not recommended due to erosion hazards. Carefully consider where the knives will be placed. When ridges are present, application knives may cause enough soil disturbance to make it difficult to plant onto ridges. In general, the shoulder of the ridge is the best placement compromise. See NebGuide G90-996, *Ridge Plant Systems: Fertility* for more information.

Choosing starter attachments for a planter and soil conditions is another concern. It is important that the starter opener not disturb soil in the planter furrow. Wet, fine textured soils may present a challenge and placing openers away from the seed furrow may be necessary. Another option is to place less than 50 lbs (5 lbs salt equivalent) of starter such as 10-34-0 with the seed. This

avoids the costs and trouble of using starter attachments, but reduces the quantity of nutrients that can be applied. Caution is urged when using this method since stand reduction is possible. Starter fertilizer placement directly with soybean seed is not recommended (See NebGuide G77-361, *Using Starter Fertilizers for Corn, Grain Sorghum, and Soybeans.*)

What are the relative benefits of liquid vs dry fertilizers? Generally agronomists are more concerned about the chemical form of nitrogen rather than whether it is in a solid, liquid or gaseous state. The greater loss potential from UAN solution on residue compared to urea in some cases is probably related as much or more to the chemistry of the fertilizer rather than its physical form. The ammonium fraction of UAN can be subject to almost immediate loss on some plant residues and on some soils that are high in pH and poorly buffered. With phosphorus, the choice of liquid or dry is a matter of economics and equipment and not of agronomic concern.

### Soil Sampling

Figure 5 illustrates the difficulty of sampling fields with non-uniform phosphorus distribution. Interpreting soil test results from the areas of high phosphorus will be different than samples taken from broadcast treatments. There are two issues involved:

1. Obtaining soil sample representative of the entire field.
2. The effect of the non-uniform distribution on crop yield.

Soil sampling simulations indicate that it is possible to get a representative sample even from fields with a history of banded fertilizer application such as shown in Figure 5. By taking over 20 random subsamples (the more the better) and mixing adequately, you can obtain a soil sample that reflects the "average" fertility status of the field and will ensure an accurate phosphorus recommendation.

The second question is more difficult to answer. Is crop response any different when continual broadcast phosphorus enriches the surface phosphorus level? Do enriched bands of soil have more value than uniform soil phosphorus enrichment? How high does the phosphorus concentration in an enriched band have to be before it is more productive to have two bands per row? Unfortunately, these answers are yet to be discovered. Experience and intuition suggest the following: An enriched band placed under the plant row is more efficient than the same quantity of phosphorus uniformly distributed on the soil surface. As mentioned previously, research indicates that band application is more effective in responsive soils. A random soil sampling method will result in adequate phosphorus recommendations.



## Conclusions

Producers need to evaluate their own situation to determine what fertilizer management approach is appropriate for their system. Many producers have personal preferences that may impact their decision beyond agronomic facts. For instance, many producers do not want to use a starter. They do not want the added complication of worrying about fertilizer when they are planting. They do not like the added time it takes. As we have described, there are several alternatives that can maintain soil fertility in conservation tillage systems.

The producer is the decision maker and the best decision will be a balance of the many factors and priorities under consideration. Evaluate your land, equipment, other production practices, and personal preferences — then use the knowledge of how fertilizers are affected by environmental conditions to design an effective fertilizer program for reduced tillage.

In making your decision remember these fertilizer principles:

1. Determine fertilizer rate based on soil samples.
2. When possible place nitrogen below residue and the soil surface.
3. Put immobile nutrients such as phosphorus below and beside the row in a band.

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