Chapter 4

Fertilizer and Lime

John S. Kruse

Conversion from a conventional tillage system in which the soil is worked extensively, to a conservation tillage system in which the soil is rarely or never disturbed, causes significant changes in the soil. For example, crop residues that were once incorporated into the soil are left on the surface, resulting in slower decomposition (Figure 4-1). Understanding these effects and ways to manage them can improve a producer's successful transition from tillage system to another and minimize potential problems.

Nitrogen

Nitrogen is found in many forms in the agricultural environment, and in some forms it is very vulnerable to loss. Urea or ammonium-based fertilizers, when placed on the surface, may convert to ammonia and can be lost into the air through a process called volatilization. These same fertilizer sources in the soil are converted over the growing season to nitrate, a type of nitrogen that can be lost either by leaching in porous soils or turning into nitrous oxide gas (denitrification) on heavy, water-saturated soils. Proper nitrogen placement and timing can minimize nitrogen loss and maximize a producer's fertilizer investment (Figure 4-2).

One of the biggest changes that occurs when conservation tillage is adopted is an increase in soil carbon as soil organic matter increases. Carbon and nitrogen are inextricably linked, so changes in carbon lead to changes in nitrogen availability. For four or five years after the adoption of conservation tillage, the increasing carbon in the soil leads to some nitrogen immobilization, meaning less nitrogen is available for plant uptake (Table 4-1). After this transition period, the soil reaches a new "steady state," and crop nitrogen requirements go back to what they were before the transition began. What is likely occurring during this transition is that the reduced tillage soil is building soil structure and creating large aggregates. Some soil nitrogen becomes trapped inside these aggregates and is unavailable to crops. After a few years, however, the aggregate building is complete, so applied nitrogen is available for plant use.

During the transition phase, a producer can manage by applying supplemental amounts of nitrogen. Another option available to producers is to knife-in the nitrogen below the surface residues (Figure 4-3). Microbes assimilate or "take up" large quantities of nitrogen as they decompose crop residues. This process is called immobilization and is temporary. Eventually the nitrogen is released back into the soil, but the process takes longer in conservation tillage. Placing the nitrogen below the top few inches of soil bypasses this zone of intense microbial activity and leaves the

Table 4-1. Cotton lint yields over time on a nonirrigated Gigger silt loam from the Macon Ridge. Based on tillage system. Note the trend toward lower yields from the conservation tillage systems compared to surface till during the first three years followed by a trend toward higher yields for the no-till system compared to other tillage systems.

	Cotton Lint Yield (lbs./acre)					
Tillage System	1987-1989	1990-1992	1993-1995	1996-1998	1999	2000
Surface till	667	782	834	759	414	495
Ridge till	598	726	748	723	408	511
No-till	604	809	901	772	472	526

(Source: Boquet et al., 2000. Cotton Conservation Tillage and Cover Crop Systems for Cotton on the Macon Ridge) nitrogen more available for crop use. A Kansas State University study on grain sorghum demonstrated that placing the nitrogen below the surface residue in a no-till system increased crop yield 17 to 30 percent compared to a surface broadcast application.

Conservation tillage systems are more conducive to nitrogen loss from volatilization or denitrification from surface-applied nitrogen, especially on heavier soils (up to 30 percent of the nitrogen can be lost). There are several practices a producer can use to overcome this challenge – timing, split applications, injection and enhanced-nitrogen products.

Timing: If the fertilizer application can be made just before a rainfall of at least a half-inch, the water will carry the fertilizer below the surface so it is not vulnerable to volatilization losses.

Split applications of nitrogen, at planting and at side-dress, reduce the amount of nitrogen in the field at any one time, allowing a greater percentage to be taken up by the crop. This lowers the overall amount of nitrogen vulnerable to loss.

Injecting or knifing-in the nitrogen fertilizer puts it below the surface where so much can be lost to volatilization.

Figure 4-1. Conservation tillage in Louisiana emphasizes the importance of leaving crop residue on the soil surface to reduce rainfall impact and slow runoff.

Enhanced nitrogen products such as a urease inhibitor and/or a nitrification inhibitor have the potential to reduce nitrogen losses. A urease inhibitor is applied in conjunction with fertilizers that contain urea, and it acts as a retardant to urea breakdown for a few days to a week. This allows the fertilizer more time to wash into the soil before it converts to ammonium or ammonia. A nitrification inhibitor slows the conversion of ammonium, which is bound in the soil, to nitrate, which is susceptible to leaching and runoff. Crops take up both ammonium and nitrate, so nitrogen loss in minimized while plants still have access to it.

Cover crops

Leguminous cover crops or green manure crops will decompose and release nitrogen in both conventional tillage and conservation tillage systems, but the breakdown and release of nitrogen occurs more slowly in the conservation system than the conventional one. This occurs because incorporated residues have much more surface area being attacked by soil microbes compared to the residues left on the surface. Plowed or disked soils are also generally warmer than comparable conservation tillage soils, stimulating more active microbial cover crop decomposition.

Although slower to break down and release nitrogen, the conservation tillage system releases as much total nitrogen as the conventionally tilled system. Decomposition may just take place over a larger portion of the growing season. This may actually be beneficial to the crop using it, since the nitrogen demand generally increases in most crops from spring to summer.

Phosphorus

Phosphorus binds strongly to soil and, unlike nitrogen, is very immobile. Most phosphorus losses from a conventionally tilled soil occur as a result of erosion, and since conservation tillage significantly reduces erosion, less phosphorus is lost from the soil.

The exceptions to that are soils heavily and repeatedly treated with manure that have become phosphorus saturated. In those cases, surface water runoff carries dissolved phosphorus with it, and conservation tillage systems can increase losses since much of the phosphorus is near the surface. Judicious use of manures can avoid this problem.

Soils under conservation systems are cooler and wetter in the spring than comparable conventionally tilled

Figure 4-2. Fertilizer sidedress application of nitrogen in a conservation tillage system. Note the fertilizer is knifed in several inches away from the crop row to prevent losses due to volatilization and reduce the risk of fertilizer injury.

Figure 4-3. Side view of liquid fertilizer applicator in a conservation tillage system. The fluted coulter opens a narrow furrow in which liquid fertilizer is dropped behind the knife that follows the coulter.

soils. Cooler soil conditions slow overall root growth of seedlings, sometimes inducing temporary phosphorus deficiencies. Producers should apply a phosphorus-containing starter fertilizer near the seed at planting to overcome this situation.

Other than this planting-phase situation, conservation systems generally have greater phosphorus availability than conventionally tilled soils. If soil test phosphorus levels indicate the need for increased phosphorus, surface-applied phosphorus will work well in conservation tillage since less of it is bound up in the mineral fraction of the soil. This surface application results in horizontal banding of phosphorus. Research was conducted to determine if a vertically applied band of phosphorus fertilizer would improve crops under conservation tillage, but no benefits, such as yield gain, were observed.

Potassium

Potassium uptake issues are similar to phosphorus issues in conservation tillage, since potassium – like phosphorus – is relatively immobile in the soil and tends to become concentrated near the surface in reduced tillage systems.

The implications for producers are root growth of recently planted crops will be slower under cool soil conditions and the roots must grow toward the potassium to exploit it. An addition of potash to a starter fertilizer application placed near the seed may be warranted.

Research by Schulte et al. (1978) conducted in Wisconsin demonstrated that adding potash to no-till soil systems that had medium levels of soil potassium was more critical than in tilled soil systems. The percentage of potassium in ear leaf tissue was lower under no-till, and yields were less, but the gap between the two systems narrowed as more potash was added. Thus, producers adopting conservation tillage systems should be diligent in testing soil nutrient levels and maintaining adequate amounts for optimal yields.

Lime

Soils under conservation tillage result in a concentration of nutrients and acidity near the soil surface. The acidity is primarily generated by urea and ammonium-based fertilizers that lower soil pH as microbes convert them into nitrate.

A few producers avoid this situation by using nitrate-based fertilizers, but cost and accessibility make this option impractical for most. Heavy, infrequent additions of lime create a cycle of high and low pH that keeps the soil system in a state of flux and has the potential to reduce the best possible crop performance. Optimal surface soil pH also is critical to ensure the activity of triazine herbicides.

After adopting conservation tillage, sample the top 2 inches of soil as well as the traditional 6-8 inches to get a clear idea of the soil pH picture. If the pH in the top 2 inches is reported to be less than 6.2 but the soil test from the full 6 inches does not call for lime addition, apply lime at the rate of 1 ton calcium carbonate equivalent per acre. If the pH of a soil is 5.5 or less for the full 6-inch depth, apply and incorporate the recommended amount of lime prior to adopting the conservation tillage system.

Research has indicated that over extended periods of time, conservation tillage systems do not increase the overall lime requirements of a soil compared to conventionally tilled soils. The studies only show that the lime applications should be lighter and more frequent.

Manure

Researchers have long noted advantages to including manure applications in a field undergoing the transition from conventional to conservation tillage. Many of the benefits likely stem from the quickly available nutrient fraction of manure that feeds the soil microbial population, as well as the immediate addition of organic matter that increases nutrient and water-holding capacity. These benefits also include greater movement and availability of phosphorus due to complexation in the organic structures of the manure, improvement of soil structure that results in increased infiltration rates and increased pH and buffer capacity.

A significant portion of manure nitrogen is in the ammonium form and has the potential to be lost through volatilization if it is surface applied. Under conventionally tilled systems, the most common practice to prevent this nutrient loss is to incorporate the manure after the application – an option not available in most conservation tillage systems. Additional concerns include the effects of a potential odor problem with neighbors and avoiding compaction problems potentially created by manure spreading equipment. Thus, some thought should be given to how manure can be used in a conservation tillage system.

When manure odors present a potential problem, producers can work with their neighbors by choosing cool days to apply. Warmer weather increases volatilization and the intensity of the odors. People also are more likely to be outdoors and have open windows during warm weather. Wind direction and the rain forecast also should factor into the decision.

If possible, manures should be applied on days when the wind direction will carry odors away from neighbors. Rainfall that occurs very soon after a manure application will incorporate much of the manure into the soil and will greatly reduce the intensity of odors. A half-inch of rain is comparable to physical incorporation. More rainfall than a half-inch may lead to nutrient-laden manure running off the field, but that depends on how saturated the field already is and how quickly water infiltrates the soil.

Although sometimes difficult to find, specialized equipment that injects manures below the surface, while only minimally disturbing the soil, has been manufactured and may be available. Research is needed in Louisiana to evaluate the benefits and potential drawbacks of these systems on the various soil types found throughout the state's crop-producing regions.

Producers should be aware of compaction caused by manure application equipment. The primary way to avoid soil compaction is to use equipment with flotation tires. Just as important is timing. Apply the manure at a time when the soil is not excessively moist to minimize ruts in the field during application. Some application systems use drag hoses that require less manure weight to be loaded onto the application equipment.

Summary

Producers who adopt conservation tillage methods can successfully manage the transition period from conventional tillage to the new system. As with all agricultural systems, thoughtful planning and an awareness of the issues involved can ensure a profitable transition.