Resources Conservation Practices

Tillage, Manure Management and Water Quality

Conservation Quiz

1. How do intensive tillage and surface manure application impact water quality?

2. What are the two tests to manage and evaluate nitrogen use efficiency?

3. What components are considered in the Phosphorus Index to determine phosphorus movement risk?

Answers on page 5.

Tillage and manure application practices significantly impact surface and ground water quality in Iowa and other Midwestern states. Tillage and manure application that incorporates residue and disturbs soil result in higher levels of soil erosion and surface runoff. Phosphorus and sediment loading are closely linked to the increase in soil erosion and surface water runoff. Manure application (i.e., injection or incorporation) reduces surface residue cover, which can worsen soil erosion regardless of the tillage management system being used. An integrated system approach to manure and tillage management is critical to ensure efficient nutrient use and improvement of soil and water quality. This approach, however, requires changes in manure application technology and tillage system management to ensure the success of an integrated system.

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Tillage, Manure Management, and Soil Erosion

Tillage and manure management systems vary in their degrees of surface soil disturbance. Some manure application and tillage implements disturb the soil surface significantly while others create minimal surface disturbance. Manure injection or incorporation is a tillage system that incorporates liquid manure below the soil surface. Because of this dual purpose of manure application and tillage disturbance, this process needs to be managed properly to minimize the potential for surface runoff.

It is well documented that liquid manure application systems can reduce residue cover. (See ISU Extension publication PM 1901g). Both tillage and manure application reduce the amount of surface residue left on the soil surface. It is important to minimize the incorporation of surface residue in order to decrease sediment and nutrient losses in surface runoff. Tables 1 and 2 show the amount of surface residue left on the soil surface after tillage and manure application as well as the effect of these operations on soil erosion.

Soil erosion can have a significant impact on soil productivity and environmental quality. Severe soil erosion results in significant losses of topsoil. A topsoil loss of 12 inches can result in a 70 percent reduction in crop productivity (Al-Kaisi, 2001). While soil erosion reduces crop productivity on site, it can degrade water quality due to nutrient and sediment loading to surface water and nitrate contamination of ground and surface water. Soil water erosion is the main mechanism for transferring phosphorus to lakes and streams. Finer soil particles or sediments are the major carriers for phosphorus. However, dissolved phosphorus in organic or inorganic forms can be carried by water runoff as well.

To improve surface water quality, residue needs to be managed more efficiently by improving tillage and manure application technologies. Improvement of manure application technology can lead to less soil disturbance and residue burial while using manure application as a component of a tillage system.

For the past few years, strip-tillage has been used as a dual system for managing commercial nitrogen fertilizer (i.e., anhydrous ammonia) and tillage at the same time. This concept of a tillage and nutrient management system can be implemented in liquid manure application.

Table 1. Residue cover and soil loss with soybean residue for various integrated tillage and manure management systems.*

Management System	Residue Cover (%)	Soil Loss (T/acre)	Relative Soil Loss (%)**
Tillage operations and manure application effects on residue cover			
Fall shovel injected, fall chisel plow, spring field cultivation, planting	1.9	23.4	- -
Fall shovel injected, spring field cultivation, planting	3.4	19.9	85
Fall disc-covered, fall chisel plow, spring field cultivation, planting	5.7	16.9	72
Fall disc-covered, spring field cultivation, planting	10.3	13.4	57
Spring slot injected, planting	35.3	6.2	26
Tillage operations only effects on residue cover			
Moldboard plow, spring field cultivation, planting	1.0	26.9	- -
Chisel plow, spring field cultivation, planting	13.7	11.8	44
Fall-strip tillage, spring field cultivation, planting	24.2	8.4	31
Spring field cultivation, planting	34.3	6.4	24
Planting	42.8	5.1	19

*Calculations were based on ISU Extension publication PM-1901a and MWPS-45 for a 5% slope in central Iowa.
** Relative soil loss is based on fall shovel injected, fall chisel plow, and moldboard plow soil losses.

Tillage and Manure Management Considerations for Nitrogen Use

Nitrogen is often considered the most limiting nutrient for corn production. It also is an abundant plant nutrient found in manure. Research has shown that nitrogen loss due to ammonia volatilization from surface applied liquid manure can be very significant depending on the time of application, weather conditions, and method of application (Al-Kaisi and Waskom, 2002). Alternatively, liquid manure injection can significantly reduce nitrogen loss due to ammonia volatilization to as low as 3 percent depending on injection depth, soil closure, soil moisture, and air temperature.

Tillage systems can greatly affect the amount of soil nitrogen left in the soil at the end of the growing season. Figure 1 shows a comparison between three different tillage systems where chisel plow and strip-tillage resulted in higher amounts of residual soil nitrogen in the top 24 inches of soil compared with no-tillage. However at soil depths of 24 to 48 inches, no-tillage and strip-tillage resulted in lower soil nitrogen than chisel plow. Differences in residual soil nitrogen can be attributed to the effect of tillage system on changing soil physical properties such as infiltration rate. Under no-tillage water infiltration rate is much higher and subsequently more nitrogen can be lost to tile drains compared with other tillage systems. An Iowa study has documented greater nitrogen losses in tile drains from no-tillage systems compared to conventional tillage systems (Weed and Kanwar, 1996).

To better use nitrogen there are several methods that can be used to evaluate nitrogen availability and use. The late spring soil nitrate test indicates how much nitrogen is available for crop growth early in the season. If soil nitrogen is low additional nitrogen can be side-dressed to meet crop requirements. By using the late spring nitrate test less manure or commercial nitrogen can be applied prior to planting, promoting environmentally sound practices. Alternatively, at the end of the season the fall stalk nitrate test can be used to evaluate the overall nitrogen management program. This test measures the amount of nitrate-nitrogen in the corn stalk at maturity. A high level of nitrate-nitrogen concentration (above 2000 ppm) in the stalk indicates luxury nitrogen consumption, due to high nitrogen application or low nitrogen utilization for grain production during the season. This test can be used for evaluating the previous year's nitrogen fertility program and the necessary adjustments that can be made (See ISU Extension publications PM 1584 and PM 1714 for more information on nitrogen management).

Table 2. Residue cover and soil loss with corn residue for various integrated tillage and manure management systems.*

Management System	Residue Cover (%)	Soil Loss (T/acre)	Relative Soil Loss (%)**
Tillage operations and manure application effects on residue cover			
Fall shovel injected, fall chisel plow, spring field cultivation, planting	23.0	5.0	- -
Fall shovel injected, spring field cultivation, planting	29.4	4.4	88
Fall disc-covered, fall chisel plow, spring field cultivation, planting	28.1	4.5	90
Fall disc-covered, spring field cultivation, planting	36.0	3.9	78
Spring slot injected, planting	65.4	2.4	48
Tillage operations only effects on residue cover			
Moldboard plow, spring field cultivation, planting	1.0	26.9	- -
Chisel plow, spring field cultivation, planting	13.7	11.8	44
Fall-strip tillage, spring field cultivation, planting	24.2	8.4	31
Spring field cultivation, planting	34.3	6.4	24
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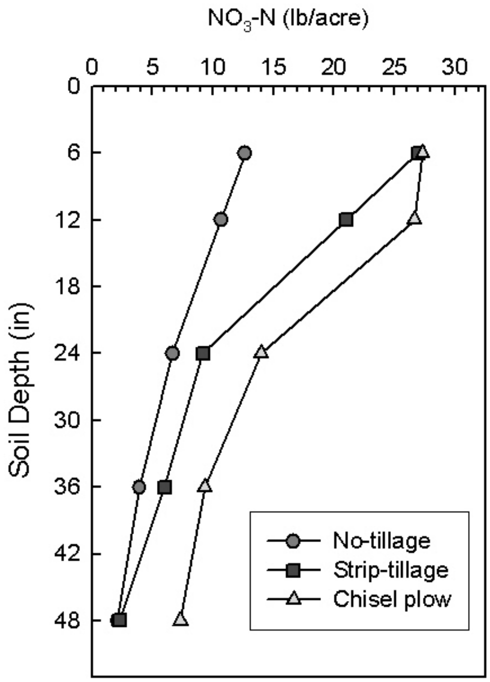

Figure 1. Post-harvest soil nitrate-nitrogen profile for three tillage systems at 225 lb/acre total nitrogen of liquid swine manure (Al-Kaisi et-al., 2004).

Considerations for Maximizing Manure Use Efficiency

1.Take a representative manure samples for nutrient analysis. Thoroughly agitate manure pits to obtain a well mixed manure sample for nutrient analysis prior to manure application.

2.Take soil samples for nutrient analysis of nitrogen (N), phosphorous (P), and potassium (K) and determine the actual crop needs for these nutrients.

3.Calibrate manure application equipment. Before applying manure calibrate manure application equipment to ensure the desired application rate based on manure management plans.

4.Consider timing and conditions when applying manure. Early spring rain can cause significant nitrogen and phosphorus losses of fall applied manure. Spring applied manure can minimize nitrogen and phosphorus losses and increase crop utilization efficiency.

5.Apply manure using injectors that cause minimal soil and residue disturbance (i.e., slot injectors). This kind of injector leaves more residue cover on the soil surface reducing potential soil erosion and nutrient losses.

Tillage and Manure Management Considerations for Phosphorus Use

Phosphorus is a necessary nutrient for plant growth and development. However, when phosphorus is carried to surface water by sediment transport it becomes an over abundance in the water creating an environment for algae growth. Algae growth leads to eutrophication (aquatic plant growth) resulting in the depletion of dissolved oxygen of surface water. Since phosphorus loading can be directly linked to sediment transport through surface runoff, soil erosion and surface water runoff must be minimized to improve surface water quality.

Best management practices are recommended for improving phosphorus use efficiency by crops. Broadcasting is traditionally used for phosphorus application, because it is a low cost application method. Tillage systems can impose certain limitations on phosphorus management especially with no-tillage, ridge-tillage, and other reduced tillage systems. However 2x2, also known as deep banding, offers equivalent crop responses compared to broadcasting (Sawyer et al., 2002). The other consideration for deep phosphorus placement is related to water quality concerns. The potential of phosphorus losses from fields due to soil erosion and surface runoff is much greater when it is broadcasted on the soil surface or manure is not incorporated or injected into the soil.

Managing phosphorus can be enhanced by using tools such as the Iowa Phosphorus Index. The Phosphorus (P) Index is an assessment tool with three major components: soil erosion, surface runoff, and soil infiltration and leaching. The P Index uses soil nutrient factors, nutrient application factors, soil transport factors, and soil drainage factors to determine the phosphorus movement risk for site specific management (NRCS, 2001).

The P Index is a tool for identifying fields that have low to very high risk of phosphorus delivery to surface water and the need for conservation practices for manure or fertilizer phosphorus management. Two management practices minimize the impact of manure application on phosphorus loading. First, manure should be applied at rates that do not exceed crop requirements. Second, manure should be applied using an applicator toolbar that minimizes soil and residue disturbance.

Grain Yield Response to Nitrogen Management

A tillage and manure demonstration and research study was conducted in northeast Iowa from 2002 to 2004 to evaluate nitrogen and tillage management effects on corn yield in a corn-soybean rotation. Four total nitrogen rates of liquid swine manure of approximately 0, 75, 150, and 225 lb/acre were used in this study. Due to manure application variation, desired total nitrogen rates were not always achieved.

Corn yields were normalized as relative yields for all sites to account for variability in nitrogen rates. Relative yield is the ratio of grain yield at any rate to the maximum grain yield achieved for each site. The maximum nitrogen rate (MNR) and economic optimal nitrogen rate (EONR) were determined by solving a quadratic plateau equation that was fitted through the data points of relative yield versus nitrogen rates by taking the first derivative of both sides of that equation (Fig. 2). Then the change in relative yield over Nitrogen rate was set to be equal zero to determine MNR. To determine EONR the change in relative yield over nitrogen rate was set to be equal to 0.10 ratio of nitrogen to corn prices (the nitrogen fertilizer price assumed to be $0.20 or $0.30/lb and corn price was $2.00 or $3.00/bushel). Therefore, by solving these relationships MNR was 212 lbs N/acre, while the EONR was 133.0 lbs N/acre in this study.

It was found in this study that the relationship between late spring soil nitrate-nitrogen concentration and nitrogen rate application was linear. This relationship means a steady increase in soil nitrate-nitrogen concentrations was increases of nitrogen application rates. Using the EONR of 133.0 lbs N/acre the estimated the late spring soil nitrate-nitrogen concentration to be 14.4 ppm (Fig. 3). Similarly, at a MNR of 212.4 lbs N/acre a late spring soil nitrate-nitrogen concentration of 19.9 ppm was estimated. At both the EONR and MNR no additional nitrogen would be required.

The fall stalk nitrate-nitrogen concentrations showed that 175 lb N/acre is the break point between optimum and excessive nitrate-nitrogen concentration in corn stalks (Fig. 4). Additional nitrogen beyond 175 lb N/acre would result in higher stalk nitrate-nitrogen concentrations (luxury nitrogen use) and low yield increases.

Answers to Conservation Quiz

1. Intensive tillage and manure mismanagement can negatively affect water quality by increasing soil erosion, sediment delivery, and phosphorus loading to surface water.

2. The late spring soil nitrate test evaluates nitrogen availability in-season, while the fall stalk nitrate test evaluates the use efficiency of nitrogen at the end of the season.

3. Soil erosion to surface water, surface runoff to surface water, and subsurface drainage or leaching.

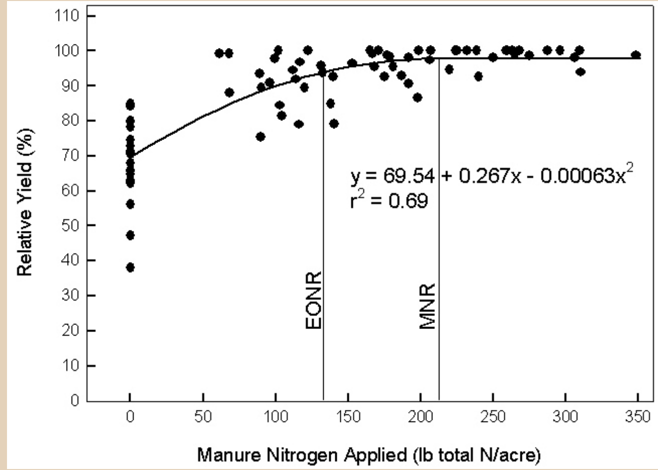

Figure 2. Relative corn yield as a function of total nitrogen of liquid swine manure, MNR is maximum nitrogen rate and EONR is economic optimum nitrogen rate.

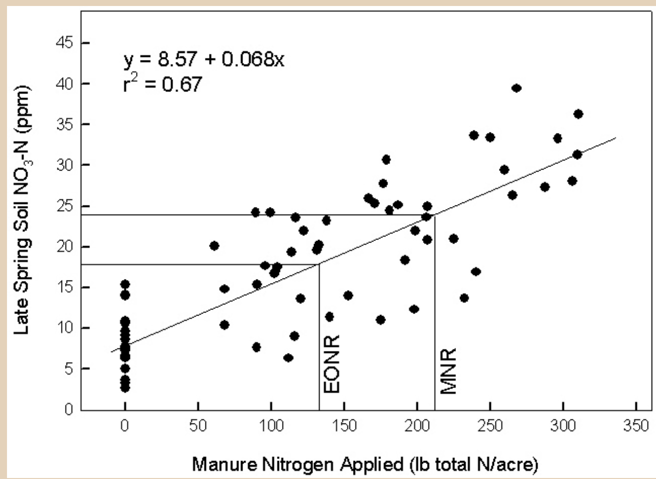

Figure 3. Late spring soil nitrate-nitrogen concentration as a function of total nitrogen of liquid swine manure.

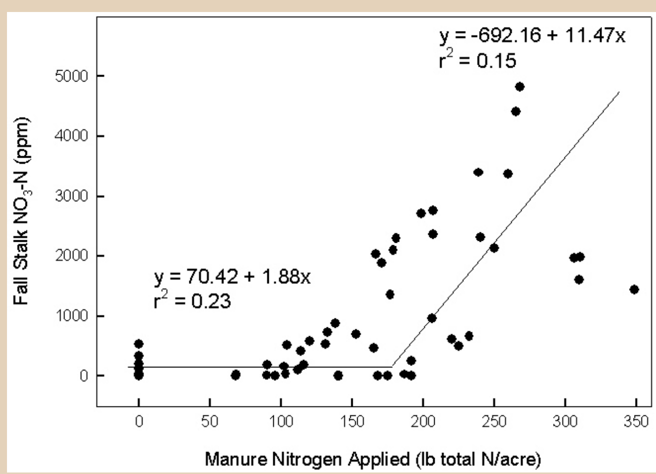

Figure 4. Fall corn stalk nitrate-nitrogen as a function of total nitrogen of liquid swine manure.

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Resources Conservation Practices: Manure and Tillage Management is published by Iowa State University Extension with funding support from the USDA Natural Resources Conservation Service through Cooperative Agreement No. 74-6114-0-2.

Some information used in this publication is from a project funded by the Integrated Farm and Livestock Management Demonstration Program according to cooperative agreement 04IFLM002.

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Issued in furtherance of Cooperative Extension work, Acts of May 8 and June 30, 1914, in cooperation with the U.S. Department of Agriculture. Stanley R. Johnson, director, Cooperative Extension Service, Iowa State University of Science and Technology, Ames, Iowa.

PM 1901h April 2005