Nitrogen Management: Proper Accounting and Utilization of Nitrogen Resources[1]

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Introduction

Experience from research over the past 20 years in Nebraska has shown that ground water quality can be significantly influenced by nitrogen (N) fertilizer management, particularly over shallow aquifers. Nitrate concentrations of ground water in many aquifers has steadily risen as nitrogen gradually leaches from the crop root zone into the aquifer. Although inorganic fertilizers are often a major source of nitrate entering ground water, organic sources of N, such as manure and sewage sludge, can contribute significantly to ground water nitrate contamination as well.

Over the past 20 years, we have learned that it is important to account for all sources of N available to a crop before applying fertilizer. The accounting process allows proper credit for N already in the soil as nitrate, for N present in irrigation water, for N derived from waste products such as manures and sludges, and for N contributed through mineralization of legume residues. After properly crediting various sources of N, we have studied additional management tools to maximize the efficiency of fertilizer N - such as when to apply fertilizer, where to place it, and how to use supplemental tools, such as nitrification inhibitors, to increase efficiency. Two NebGuides which summarize current Nebraska recommendations for nitrogen fertilizer management for irrigated corn are G87-829, *Fertilizer Nitrogen Best Management Practices*, and G89-913, *Adjusting Nitrogen Fertilizer for Corn Based on Nitrate Levels in Soil and Irrigation Water.*

We should not leave the impression that we know everything there is to know about nitrogen management for maximum efficiency. Far from it. As research continues, we learn more about the transport and fate of N in soil. In particular, the combination of irrigation management, especially furrow irrigation, with nitrogen management is an area that has much potential. By increasing the efficiency of use of both nitrogen and irrigation water, we can reduce the amounts of N and water needed without reducing yield potential, and at the same time minimize the transport of nitrate below the root zone.

Following are examples of current research in three areas to further increase N and water

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use efficiency, and thereby reduce nitrate leaching. These three areas are; proper credit for soybeans as a previous crop, spatial variability of nitrate in fields, and proper credit for organic wastes.

Nitrogen Credit for Soybeans as a Previous Crop

Current Extension recommendations in Nebraska suggest that N rates be reduced by 30-50 lb/acre following soybeans for corn and grain sorghum. This recommendation is based on past research which has shown an apparent need for lesser amounts of fertilizer N for corn following soybeans.

A study has been conducted from 1988 to 1990 to further refine fertilizer N rates for corn following soybeans. This study has not attempted to account for the rotational effect (benefits to yield separate from N) of soybeans as the crop preceding corn. It has instead attempted to better define the amount of N credit which can be given due to soybeans as the preceding crop without reducing yield. This study was conducted on farmers fields in south-central Nebraska. All sites were irrigated. Nitrogen was applied at rates from 0 to 200 lb/acre. Research was conducted at a total of 18 sites over the three year period.

Past research has shown that, contrary to the beliefs of some producers, relatively little nitrate-N remains in the root zone after soybeans. In fact, soybeans use nitrate present in the soil quite efficiently. Results from recent research support this (Figure 1). Average nitrate-N levels in the top six feet of soil were 60, 85, and 57 lb N/acre in 1988, 1989, and 1990, respectively. These levels of nitrate are low enough that relatively little credit would be given to the following crop, based on soil residual nitrate alone. Averaged over the three years, 17 lb N/acre credit would normally be given for nitrate in the soil.

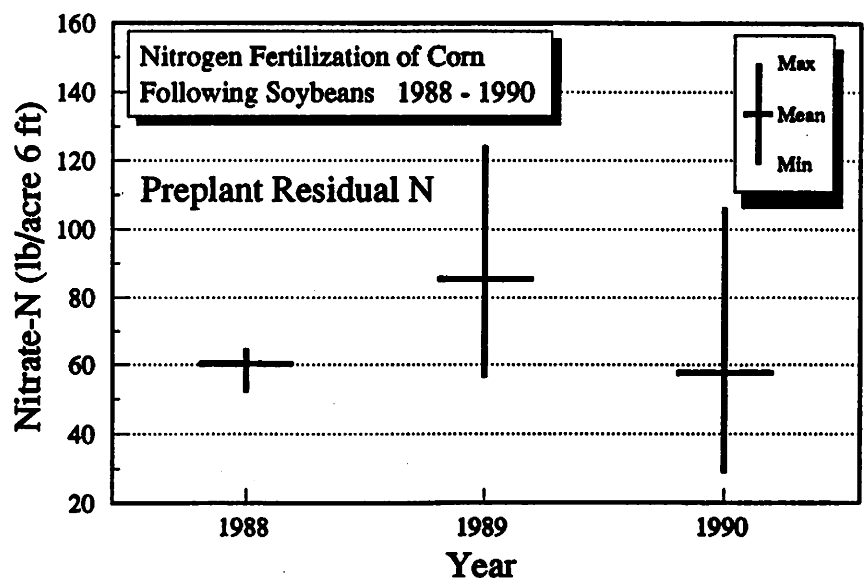

Figure 1. Average, maximum, and minimum residual nitrate-N values, 1988 - 1990.

However, grain yields over the three year period of the study show that fertilizer N rates could be reduced considerably more than that suggested based only on soil residual nitrate, without reducing yields. Examining data averaged across sites (Figure 2), yield was optimized with only 40 lb/acre of fertilizer N in both 1988 and 1989. No increase in yield was observed on both years with N rates up to 200 lb/acre. In 1990, yields increased with N rates up to approximately 120 lb N/acre (Figure 2). In 1988 and 1989, the UNL recommended fertilizer N rate (allowing 50 lb/acre credit for soybeans) for the average maximum yield was still considerably in excess of the amount of N required to optimize yield - approximately 100 lb/acre too high in 1989, and 55 lb/acre too high in 1988. In 1990, the UNL recommended fertilizer N rate was quite close to the amount required to optimize yield. These are only preliminary results from this study - more data is yet to be collected and analyzed economically to better define the optimum credit in any year for soybeans. However, these results indicate that current Extension recommendations are certainly safe from the standpoint that yield potential should not be reduced by reducing fertilizer N rates for corn by 50 lb/acre following soybeans.

Spatial Variability of Nitrate in Fields

Soil sampling for nitrate-N has been used as a research tool for the past 25 years or so. Enough information has been collected on taking deep (2 ft or greater) soil samples for nitrate that deep sampling for nitrate is a current best management practice (BMP) in Nebraska. However, there is still much to learn about nitrate in soil, particularly about its distribution and how nitrate levels are affected by cropping history. Figure 3 illustrates the relationship of nitrate-N in the crop root zone to nitrogen fertilizer applied, from fields in the N fertilization of corn following soybeans study in 1989. Basically, there is very little relationship - nitrate-N is so variable in soil that no significant differences are observable, even between the unfertilized plots and plots receiving 200 lb N/acre. Over the past three years, soil fertility researchers in the Department of Agronomy with UNL have been conducting a research study of the spatial variability of nitrate on farmers fields. To date, approximately 40 sites have been sampled in a grid fashion to a depth of 4 ft. One goal of

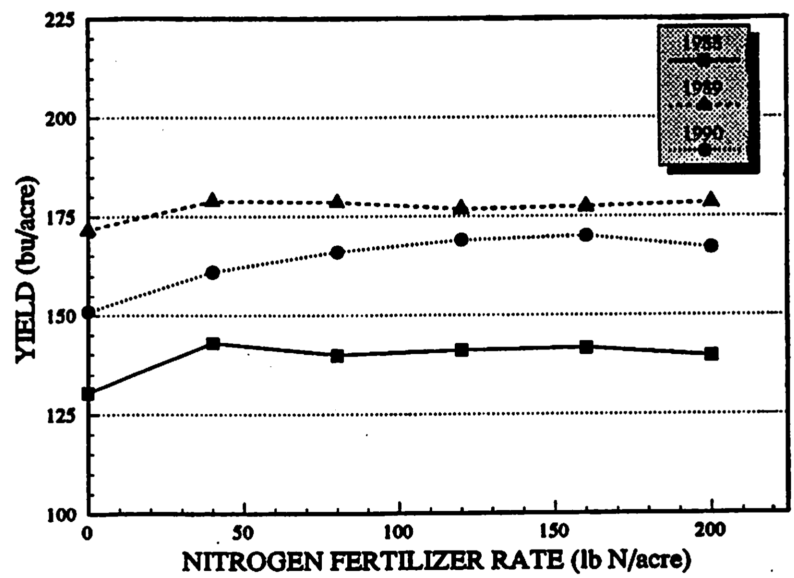

Figure 2. Grain yields of corn following soybeans, 1988 - 1990.

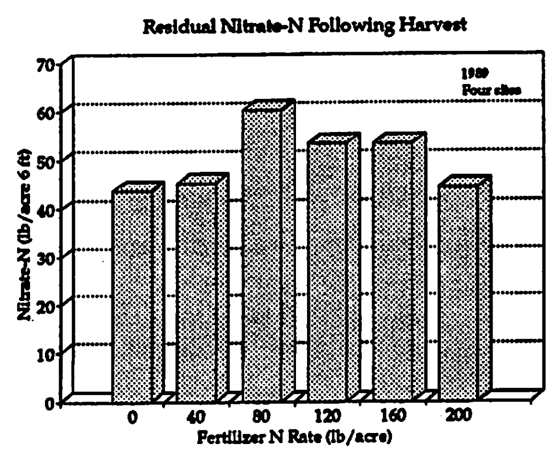

Figure 3. Average nitrate-N levels following harvest in 1989.

the research is to better define the number of samples required, and perhaps sampling patterns, to accurately represent the average nitrate level in the field. Current Extension recommendations suggest that 10-15 cores from fields no larger than 40 acres should be collected for residual nitrate analysis. Preliminary results from the spatial variability study suggest that perhaps even more samples are needed. To even be within plus or minus 20% of the true mean, 80% of the time, requires a minimum of 14 cores per field on average. The range for fields in the study was a minimum of 4 cores up to a maximum of 31 for this level of accuracy.

Figure 4 illustrate the potential for variability in nitrate-N levels in fields in the vadose, or unsaturated, zone beneath the root zone. These samples were collected from drillings conducted as part of a site evaluation for a proposed landfill for Holdrege. Figure 4 illustrates cumulative nitrate-N levels to a depth of 60 ft at various locations in the 160 acre tract. For the most part, the field has been cropped to continuous corn for the past 15-20 years, with fertilizer N rates in the range of 200 lb/acre. The majority of the cumulative N in Figure 4 is in the vadose zone, below the depth at which it is accessible to crops, and consequently is gradually moving towards the aquifer.

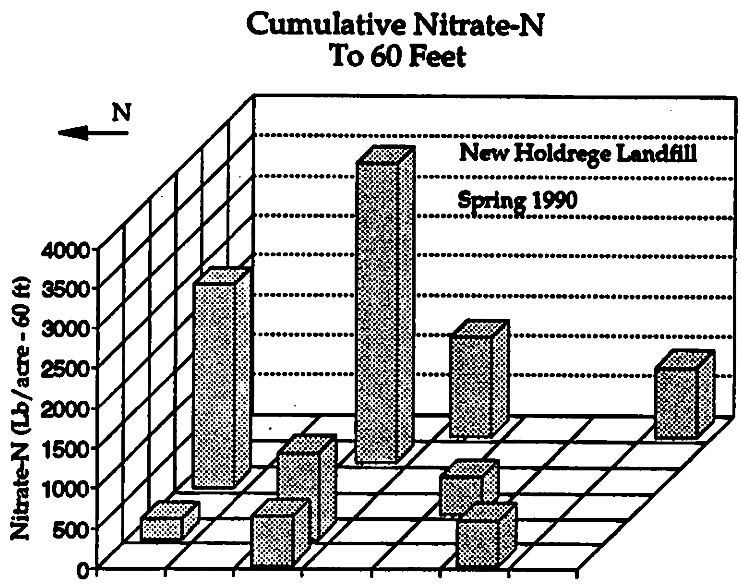

Figure 4. Distribution of nitrate-N to a depth of 60 feet over a 160 acre tract of land near Holdrege, NE.

Figures 5 and 6 illustrate the vertical distribution of nitrate in the vadose zone of two sites sampled in Phelps county in the spring of 1990. Both fields have been furrow irrigated for a number of years. Figure 5 shows a minimal amount of nitrate at the upper end of the field in the profile to 30 ft depth. The lower end of the field has a bulge of nitrate at a depth of approximately 11 ft. Figure 6 shows a significantly greater amount of nitrate in the top 8 ft at the lower end of the field, compared to the upper end. Figure 6 also shows a slight bulge in nitrate at both the upper and lower ends of the field at a depth of approximately 11 ft. Both fields appear to be typical of nitrate concentration profiles in furrow irrigated fields. The upper end of furrow irrigated fields is flooded with water for longer periods of time compared to the lower end, and consequently deep percolation is greater at the upper end of the field. Water percolating through the profile carries nitrate with it. Consequently, nitrate is leached more rapidly from the upper end of furrow irrigated fields. Figure 7 illustrates this concept. As

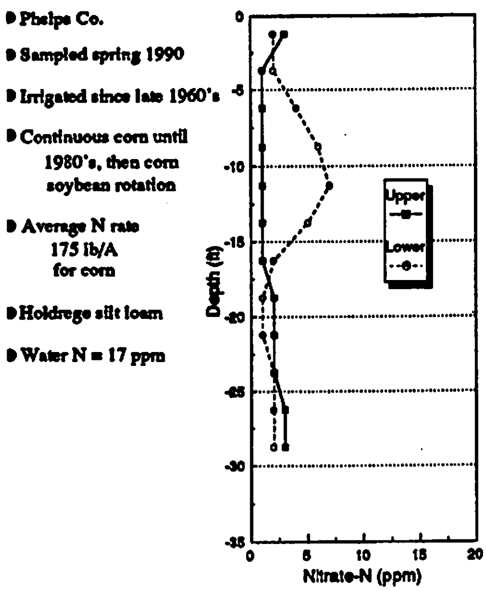

Figure 5. Vadose zone nitrate-N distribution, Phelps County site PHSH, spring, 1990.

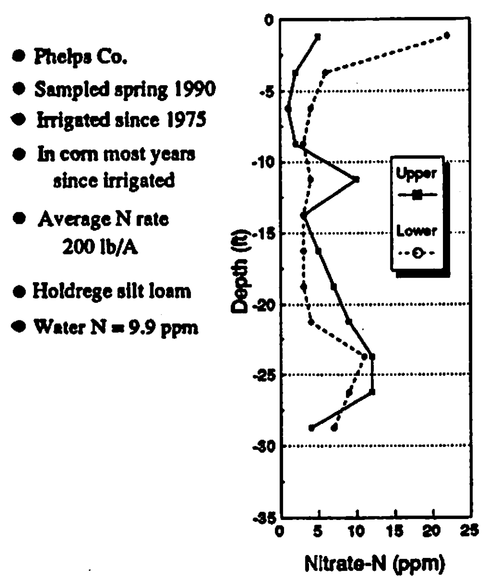

Figure 6. Vadose zone nitrate-N distribution, Phelps county site PHCE, spring, 1990.

water is applied at the upper end of the field, deep percolation losses potentially are much greater at this end of the field.

Proper Credit for Organic Wastes

Deciding upon the amount of N credit to allow for organic waste materials, such as manure, sewage sludge, composted paunch manure, etc, has been somewhat of an art in the past. Organic wastes contain a mixture of inorganic N, which are generally useable by plants, and organic forms of N, which are not plant available. Additionally, there are an abundance of organic compounds in waste materials, which vary in their stability and potential to decompose to inorganic forms. Ideally, the exact content of available inorganic N and slowly available organic N would be known for any source of waste. This requires a lab analysis of a sample of the material. Even then, different organic compounds will mineralize N at different rates. Inorganic N in the form of ammonium can be volatilized to the atmosphere during and after application. These volatile losses of ammonia can be a significant portion of the inorganic N content of the material. Consequently, the method of application, and the time following application before incorporation should be considered.

A variety of factors often result in inefficient utilization of nutrients, particularly N, from waste

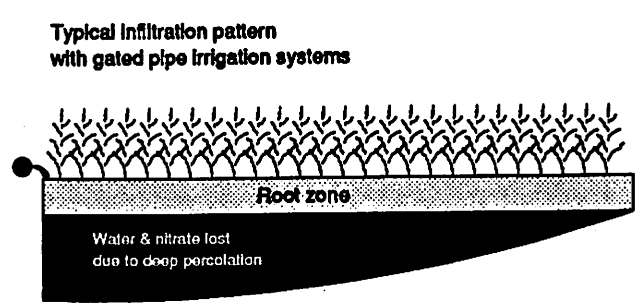

Figure 7

products. The volume of waste in large feedlot operations often results in land application which is primarily to dispose of the material, rather than to utilize the nutrients in the waste to the maximum extent possible. Also, application equipment often is poorly calibrated, resulting in broad ranges of application rates, and uneven distribution of materials.

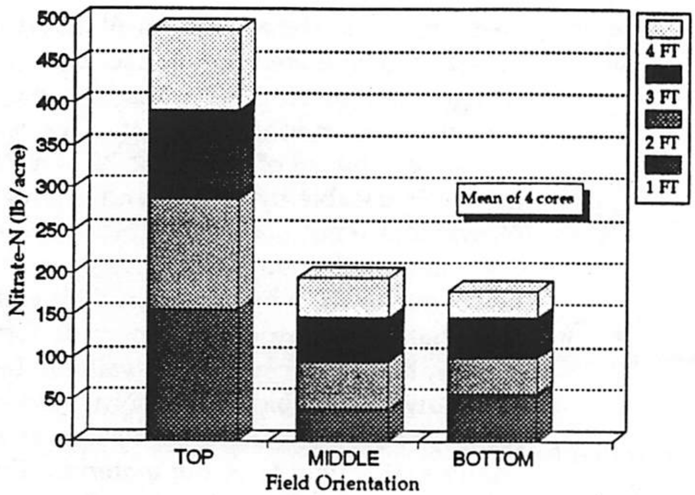

Figure 8. Accumulation of nitrate-N by 1 ft increments, field fertilized with swine slurry manure for several years.

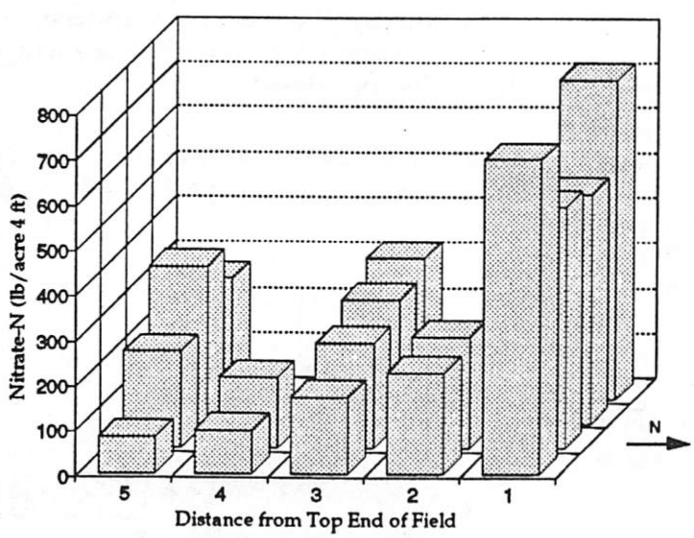

Figure 9. Distribution of nitrate-N across the field following application of swine slurry manure for several years.

Figures 8 and 9 illustrate the accumulation of nitrate-N in the crop root zone following application of swine manure over a number of years. Figure 8 shows the accumulation of nitrate by depth, in 1 ft increments to 4 ft, at the top, middle, and bottom end of a furrow irrigated field. In this case, gated pipe has been used to distribute swine slurry manure in the field. The slurry was applied directly, with no dilution by irrigation water. Much of the N content of the slurry has remained at the upper end of the field. This is consistent with the infiltration pattern illustrated in Figure 7. Consequently, the field has an accumulation at the upper end of the field, in the 4 ft root zone, in excess of 450 lb nitrate-N per acre. The middle and lower end of the field have nitrate-N accumulations in the root zone between 150 and 200 lb nitrate N per acre.

Figure 9 illustrates the accumulation of nitrate-N to 4 ft both across and down the field. Again, much of the N applied in the slurry has infiltrated into the top 20% of the field, with cumulative amounts in the bottom 20% of the field sometimes only 10% of the N at the upper end of the field. Such a distribution pattern will make it difficult to account for nitrate-N in the soil when deciding upon the proper fertilizer N rate. Residual nitrate-N in the southeast corner of this field is low enough that some fertilizer N will be required. The northwest corner, with almost 700 lb nitrate-N/acre, has N available far in excess of crop requirements.

This field is perhaps an extreme case, but illustrates a couple of points regarding management of organic wastes:

1. Know the nutrient content of the material - preferably by laboratory analysis. With knowledge of the amount of N, P, etc that is contained in the material, proper nutrient credit can be given.

2. Apply the material in a uniform manner. This will help maximize the use of the nutrients, and avoid excessive accumulations in the soil.

More information about managing manures and other waste materials as nutrient resources can be found in NebGuide G87-829, *Fertilizer Nitrogen Best Management Practices*, and Extension Circular 89-117, *Fertilizing Crops With Animal Manure.*

Summary

The above three examples of accounting for nitrogen in soil, and what can occur when best management practices are not followed, illustrate current research and demonstration project efforts to improve nitrogen management. In most cases, nitrate-N that is below the root zone, or 4-6 ft for most crops, will gradually continue to leach downward until it enters the aquifer. Consequently, good nitrogen management focuses on providing adequate N for crops while at the same time minimizing the accumulation of nitrate in the root zone, and managing irrigation to minimize the transport of nitrate below the root zone.

Acknowledgements

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