Effect of split N-fertilizer applications on drainage water quality and NO$_3$-N leaching

Background and goals

Because nitrogen (N) is essential to crop plant growth and development, farmers have used N fertilizers increasingly to make crop production profitable. But in many cases, 50 percent or less of this fertilizer is actually used by the crop in a given year. The remainder either percolates (leaches) out of the soil to groundwater, washes off, evaporates or dissolves in water in a process called denitrification, or stays in the soil where it may be useful for a later crop.

The N that leaves the soil presents environmental, economic, and energy conservation concerns. And agriculture is increasingly targeted as a potential source of water pollution; indeed, the effects of increased fertilizer use, changing tillage practices, diverse drainage systems, and other crop production practices on water pollution may be not only pervasive but multifaceted.

More and more farmers are responding to these concerns by trying conservation tillage. Because tillage practices directly affect subsurface soil-water properties and thus leaching characteristics, much recent research has focused on the fate of N under these practices.

This project measured the effects of dividing N over several applications (1) on drainage water quality, and (2) on the loss of nitrate-nitrogen (NO$_3$-N) through subsurface drainage water and below the root zone. NO$_3$-N is a mobile form of N that is easily taken up by crop plants but that can also leach (percolate) to groundwater.

This project builds on research funded by the Iowa State Water Resources Research Institute from 1984 to 1986 in which investigators established field plots at the Iowa State University Agronomy and Agricultural Engineering Research Center in Boone County, west of Ames, Iowa. They studied the effect of multiple applications, at a reduced total rate of 112 pounds (lb) per acre compared to a single application of 156 lb/acre, under no-till practices only. But a need for information on the effect of split N applications on drainage water quality and nitrate leaching through tile lines under conventional tillage prompted the project described here.

Approach

In this study, researchers used field experiments to determine the major N and water transport processes in the soil profile and investigate their interactions. Water table wells and piezometers (fluid-pressure calculation devices) installed in the field monitored the soil moisture and N fluxes (flow rates) by depth and location. As tillage and split N application were varied over time, researchers recorded changes in drainage-water quality and quantity.

The field experiment location (see Fig. 1) represented the most common Iowa agricultural watershed activities (subsurface drainage, tillage, and nitrogen management) currently used. The soils at the site were primarily deep and moderately to poorly drained. Of the subsurface drains established there, six, each draining about 0.4 hectare (one acre), were intercepted in an earlier study to investigate the interactions between tillage and N fertilizer applications. Two more subsurface drains,
which were intercepted as a part of this project by installing sumps, measured the subsurface discharge as well as collected drain water samples for NO$_3$-N.

A float-activated, continuous water-stage recorder monitored subsurface drain flow rates. Sumps dug five feet deep intercepted and provided permanent access to the drain lines. In addition to three-times-weekly sampling for water quality analyses, researchers sampled immediately after rains and snow melts to compile a detailed record of all the sources of subsurface drainage water for this area as well as the N lost to water runoff.

On the two plots instrumented for drainage water quality modeling as part of this project, researchers planted continuous corn and used conventional tillage. But instead of applying N once, they split the 112 lb/acre over three applications: 22 lb at planting, 45 lb in June, and 45 lb in July. The result was two replications of two tillage systems (no-till and conventional) and two fertilizer management practices (a single application of 156 lb/acre and a three-way-split application of 112 lb/acre) on continuous corn.

Three observation wells installed midway between subsurface drain lines measured the water-table fluctuations in each plot. The data collected allowed correlations of subsurface drain flow rates and water-table depths above the subsurface drain. Data also helped researchers to determine the slope of the water surface and the direction of lateral seepage to groundwater.

A set of piezometers installed in the plots at four depths measured the gradients, or slopes, of the area’s underground rock and sediment layers, which helped to determine the amount of percolation loss to the underground aquifer. The piezometers also sampled water to help measure more accurately the NO$_3$-N concentrations in drain water at specific locations in relation to water table depths, the loss of NO$_3$-N as water percolates to the underground aquifer, and denitrification losses if they were occurring at soil depths below or near the subsurface drain.

**Findings**

Six years’ crop data suggest that corn yields were affected neither by tillage nor by the fertilizer management schemes used in this demonstration experiment. *In fact, the yields were very similar between split N applications (totalling 112 lb/acre) and a single application (of 156 lb/acre) on no-till.*

The 1988 and 1989 yield data for the split application under conventional tillage also showed very similar yields compared to a single N application.

During the severe 1988 drought, tile lines didn’t flow and drainage water couldn’t be sampled. Data from previous years showed considerably less NO$_3$-N concentration in drainage water under no-till with split N applications at the lower total rate. Although 1989 was another very dry year when only seven samples were collected, evidence clearly pointed to decreased NO$_3$-N concentrations in drainage water when compared to conventional tillage.

These researchers are convinced that some combination of lower N rates and split N application will *decrease the amount of plant-available NO$_3$-N in soil that leaches downward and improve plant uptake of N through better timed applications.*

Efficient use of N by corn depends greatly on the amount of soil moisture available in the root zone. In addition, results from previous years suggest that a lag exists between an application and evidence of its effects, even when rainfall is adequate. Furthermore, it appears that as NO$_3$-N moves with water through the deeper, saturated soil profile, it weakens somewhat.

Finally, because the true effect of these split applications could not be assessed without significant spring and early summer rainfall that may cause tiles to flow and increase the potential for leaching, further research is needed to determine to what extent the combinations of variables—such as timing and N applica-
tion amounts, tillage, and split applications—affect yields.

Implications

As of 1990, Iowa farmers were using N fertilizer worth more than $300 million per year. Many estimates suggest that less than half of it is used by the crop; the other half remains in the soil or is lost to the environment. The data collected in this study should help to develop N fertilizer application methods that may correct this problem.

This study shows that for one set of conditions, split N applications at an overall lower rate produced yields as high as the single, higher N application. Researchers estimate that if these results could be applied across the state, Iowa farmers could reduce total N fertilizer use by about 29 percent, which would save about $86 million—or, in energy terms, the equivalent of 4.3 million $20 barrels of crude oil per year.

In summary, the results of this study indicate that water quality can be improved, and total plant uptake increased, by reducing total N and using it in split applications. Toward these goals, researchers are using data from this project to develop management practices that will reduce the impact of agricultural activities on NO$_3$-N pollution of groundwater systems.

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Fig. 1. Layout of the experimental plots to study the transport of nitrogen and water through the soil profile to the groundwater system.

Site at the ISU Agronomy and Agricultural Engineering Research Center Boone County, Iowa