Implementing nitrogen management to protect Iowa's groundwater

Background and goals
In agriculture, nitrogen (N) fertilizer recommendations historically have been based on the producer's yield goal. N supplied from legumes (soybeans and alfalfa) and manure is usually estimated conservatively to avoid any possible shortage. In Iowa, it has been generally assumed that N not used by the crop during a given growing season is denitrified (converted from nitrate, or NO$_3^-$, to nitrite) or leached into the groundwater before the following growing season.

Thus, producers have unknowingly over-applied N because they lacked a management tool for determining how much soil NO$_3^-$ would be available for the next season's crop. But in 1989 ISU introduced a late-spring soil nitrate test to assist producers in measuring the available N in the top one foot of the soil. Such information was to help farmers determine the need for additional N applied, or sidedressed, to crop plants when they are between 6 and 12 inches tall.

Fine-tuning of N application rates is needed. Drinking water on farms in many areas of Iowa is withdrawn from shallow wells that are recharged locally from row-crop acres. In some counties in northwestern Iowa, over 40 percent of the wells tested in 1990 exceeded the drinking water standard for NO$_3^-$ set by the U.S. Environmental Protection Agency (EPA).

Because N in drinking water poses a potential health concern, these investigators set out to acquaint producers with three basic concepts: (1) high N leaching contributes to groundwater contamination, (2) tools such as the late-spring soil nitrate test are now available to accurately evaluate soil NO$_3^-$N levels, and (3) producers must implement the test's recommendations to improve water quality. The overall goal was to convince producers to use the technology to properly manage N.

Investigators established the following objectives:
1. to determine current contamination levels in tile water under typical farming practices in common northwest Iowa soils;
2. to develop demonstration sites in ten counties to demonstrate use of the late-spring soil nitrate test;
3. to correlate the late-spring soil nitrate test with the mature stalk nitrate test (another recently employed technology);
4. to provide information on N management to area farmers at field days, at meetings, and through news releases; and
5. to provide this information to state and local agencies.

Approach and methods
In spring 1989 a tile-drained field was selected on the James Hultgren farm, near Alta, Iowa, in Buena Vista County. Tillage included chisel plowing in fall and disking in spring, a typical approach in northwest Iowa. Copper tubing was installed at the site to intercept tile water for sampling. Plots were located directly over drain tiles.

Because this project was to demonstrate how normal N applications on a typical farm compared with N applications made according to test recommendations, the treatments consisted of (1) normal farm application of N fertilizer (control), and (2) N management based on the
late-spring soil nitrate test. Water quality data were collected for two years, and soil and yield data were collected for three years.

Water samples were collected from the tile lines twice each month when tile water was flowing. Soil samples were collected and analyzed for NO$_3$-N before and after each crop year. The farmer also collected machine-harvested yield data.

Investigators analyzed NO$_3$-N in soil samples taken in 12-inch increments to a depth of five feet in the spring seasons of 1990, 1991, and 1992, and in the fall of 1990 and 1991. Late-spring NO$_3$-N soil samples were collected in 1989 and 1990 when the plots were in corn; no N was applied in 1991 when soybeans were grown.

The spring of 1989 was dry, resulting in little drainage flow. Because late-spring soil test results indicated 28.5 ppm NO$_3$-N in the soil, no N fertilizer was recommended for the plot. In contrast, 1990 was a wet spring. Then, 73 lb/acre of preplant N was recommended from early spring soil testing in April. An additional 100 lb was applied in June according to the late-spring soil nitrate test. The spring of 1991 was also wet. (The site was planted to soybeans that year, so no N was applied.)

No N was applied to the corn crop in 1989 on the late-spring soil test plot (the ISU line in Fig. 1), while 263 lb/acre N were applied to the farmer plot. The ISU plots received 73 lb/acre N in May 1990, whereas the farmer plots received 193 lb. In June, the late-spring soil nitrate test showed 15 ppm of NO$_3$-N, a level that suggested more N was needed. An additional 100 lb of N was applied to the ISU plots; this application may explain the increases in NO$_3$-N concentration after May 15 and June 29 under those plots. In 1991, when no N was applied to the soybean crop, differences in NO$_3$-N concentrations were small. (The nitrate concentrations in the tile water still exceeded the standard when the crop was soybeans.)

**Findings**

Nitrogen fertilizer rates were 193 lb/acre on the control plot and 173 lb/acre on the ISU plot in 1990. In 1992, 100 lb/acre of commercial fertilizer was applied to both sets of plots. Water quality results (see Fig. 1) demonstrate the residual effect of the previous crop. Only two water samples collected in 1990 were within the EPA drinking water standard of 10 mg/L (milligrams per liter). These samples were on the plots that used the late-spring soil nitrate test. All samples collected under the control plots exceeded the 10 mg/L standard.
The following shows corn yields for 1989 and 1990:

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<tr>
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<th>1989</th>
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<tbody>
<tr>
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<td>N-applied Yield</td>
<td>N-applied Yield</td>
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<tr>
<td></td>
<td>(Ib/acre)</td>
<td>(bu/acre)</td>
</tr>
<tr>
<td>Control plots</td>
<td>263</td>
<td>162</td>
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<tr>
<td>ISU plots</td>
<td>0</td>
<td>167</td>
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In both years, less N was applied to ISU plots; however, grain yields were not significantly different between plots.

Water quality samples were obtained from drainage of a 100-acre mixed corn and soybean watershed (see Fig. 2) on the Hultgren farm. Although the NO₃-N levels varied by year, all concentrations exceeded the mg/L standard, with a high of 29.5 ppm in July 1991.

Investigators also sampled the top five feet of soil for NO₃-N. The samples were collected before and after each growing season. The profiles showed a high of over 300 lb N/acre in spring 1991 on the ISU plot. During the soybean crop year, over 250 lb N/acre were removed by the crop, denitrified, incorporated in soil organic matter, or leached from the soil profile on the control plot. Only small differences occurred between plots from fall 1991 to spring 1992.

While NO₃-N samples in the top five feet of soil may give a good indication of the available NO₃-N, the amount of time required for sampling is excessive. Producers who have difficulty finding time to take soil samples only one foot deep are not likely to take five-foot-deep samples.

Stalk NO₃-N concentrations were collected in fall 1990 on both the ISU plots and the control plots. Stalk NO₃-N concentrations between 250 and 1800 ppm are considered optimal. Concentrations over 1800 ppm are considered excessive. *There was a mean of 5510 ppm on the ISU plots and a mean of 7591 ppm on the farmer plots. These results indicate that both sets of plots had excessive N in 1990. Additional N recommended by the late-spring soil nitrate test was unlikely to result in additional yield in 1990.*

In summary, few samples of drainage water from plots contained less than 10 ppm NO₃-N; all plots exceeded the 10 ppm EPA standard during the growing season. Soybeans grown in 1991 without N applications all exceeded 10 ppm, with early samples exceeding 20 ppm.
Later samples tended to be lower during the soybean year, while the corn year tended to be higher. These results demonstrate that a potential problem exists with subsurface drainage water.

On the basis of the water quality results from this study as well as results from other studies, the investigators concluded that

• in dry years, the late-spring soil nitrate test is a valuable tool in reducing nitrogen application while maintaining yields;
• in wet years, the late-spring soil nitrate test recommendations were often higher than the conventional NO$_3$-N recommendations;
• for the sites tested, N recommendations based on the late-spring soil nitrate test are unlikely to reduce tile water NO$_3$-N concentrations below the EPA standard; and
• maintaining nitrate-nitrogen concentrations in tile water below the EPA standard (10 ppm) in northwest Iowa crop fields will be difficult.

Further investigation is clearly required to develop methods for protecting groundwater and surface water from NO$_3$-N contamination.

Implications

Results from this project reached area farmers through meetings and radio broadcasts. The water quality data from this project have also been shared with Extension and Soil Conservation Service personnel and producers, all of whom have become acquainted with the advantages and disadvantages of the test.

The late-spring soil nitrate test provides hope that N can be applied on the basis of soil NO$_3$-N in the top foot of soil rather than on the basis of yield goal. It appears from this research that nitrate can leach from the top one foot of soil, giving a low test result. It also appears that applying the additional N recommended may increase yields but may harm water quality as shown by the 1990 data. Complicating the situation is the fact that the late-spring soil nitrate test is still being fine-tuned.

The water quality information gained from this study demonstrates the potential problem that exists with tile drainage water in northwest Iowa; moreover, it reflects a similar situation around the state. The problem was most dramatically illustrated in the fact that no samples collected from tile lines on the control plot contained less than 20 ppm nitrate.