AN ASSESSMENT OF ON-FARM APPLICATIONS OF THE LATE-SPRING SOIL NITRATE TEST IN IOWA

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Larry J. Wilson, Director
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A Joint Report From The Integrated Farm Management Demonstration Project, the Model Farms Demonstration Project, and the Big Spring Basin Demonstration Project

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The consortium of institutions collaborating in Iowa's Agricultural-Energy-Environmental Initiative principally have included: state and federal agencies, the Iowa Department of Agriculture and Land Stewardship, Iowa Department of Natural Resources, USDA-Soil Conservation Service, the Agricultural Stabilization and Conservation Service, and the Agricultural Research Service, and the U.S. Environmental Protection Agency; state institutions, Iowa State University Extension, the Departments of Agronomy, Agricultural Engineering, Economics, Sociology, and the Agricultural and Home Economics Experiment Station, and the University of Iowa Hygienic Laboratory, the Institute for Agricultural Medicine and Occupational Health, the Graduate Program in Urban and Regional Planning; and grass roots support from Iowa Conservancy Districts and Soil Conservation Districts, as well as other private and farm interest groups, such as the Practical Farmers of Iowa and the Iowa Natural Heritage Foundation.

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Iowa Department of Natural Resources, Geological Survey Bureau
Technical Information Series 28, 1994, 18p.

G.W.Frable, G.R.Hallberg, C.K.Contant, and A.M.Blackmer

ABSTRACT

Nitrogen fertilization is essential for profitable corn production in Iowa. Nitrogen is also a major cost of production and, when lost from the cropping system, contributes to environmental problems. Since 1982, the state of Iowa has implemented a large array of programs to improve the environmental performance of agriculture as part of Iowa's Agricultural-Energy-Environmental Initiative. Improved nitrogen (N) management has been one primary objective of the programs because of regional problems with nitrate contamination of water supplies that have evolved over time and because of the clear opportunities to enhance the efficiency and profitability of Iowa farmers.

As part of Iowa's programs, intensive work began in 1985 to find and calibrate plant tissue tests and nitrogen soil tests as new tools for N management. The late-spring, or pre-sidedress soil test has shown significant potential for refining N management in Iowa and other corn producing areas. The test procedures have been tailored to Iowa conditions and afford a refined estimate of crop nitrogen needs that can then be sidedressed to the growing crop. These procedures are designed to conduct the soil sampling late enough to account for the effects of spring weather conditions yet early enough to allow the producer to sidedress additional N if needed. Various reports have documented the economic and environmental benefits of the test from controlled implementation projects. This paper reviews the results from uncontrolled user applications of the late-spring soil nitrogen test in Iowa as part of various education and demonstration programs.

The late-spring soil nitrate test has several roles in making Iowa agriculture more efficient and sustainable. It is a technical tool that can reduce inefficient nitrogen fertilizer use, while maintaining yields. As a consequence the test can improve profitability, as well as water quality by reducing N loading. It can also be used as a feedback and educational tool, even by producers who do not sidedress N, giving Iowa farmers greater insight into N fertilizer use and the factors that affect fertilization needs. The test should be used in all these varied roles to help achieve greater efficiencies in nitrogen use.

In this report, soil test and crop production results were reviewed from projects conducted by the Practical Farmers of Iowa (PFI), the Dordt College Agricultural Stewardship Center, the Farm 2000 project, a survey of N-TRAK kit purchasers, and the Iowa Natural Heritage's Resourceful Farming Demonstration Project (RFDP). These programs utilized the late-spring soil test under relatively uncontrolled conditions; hence, there are many limitations in the data. In aggregate, however, these applications demonstrate that the late-spring soil test has been successful overall in both its technical and educational roles. In most cases, the test significantly reduced N rates while maintaining crop yields. In aggregate, on an estimated

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As part of Iowa's programs, intensive work began in 1985 to find and calibrate plant tissue tests and nitrogen soil tests as new tools for N management. The late-spring, or pre-sidedress soil test has shown significant potential for refining N management in Iowa and other corn producing areas. The test procedures have been tailored to Iowa conditions and afford a refined estimate of crop nitrogen needs that can then be sidedressed to the growing crop. These procedures are designed to conduct the soil sampling late enough to account for the effects of spring weather conditions yet early enough to allow the producer to sidedress additional N if needed. Various reports have documented the economic and environmental benefits of the test from controlled implementation projects. This paper reviews the results from uncontrolled user applications of the late-spring soil nitrogen test in Iowa as part of various education and demonstration programs.

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In this report, soil test and crop production results were reviewed from projects conducted by the Practical Farmers of Iowa (PFI), the Dordt College Agricultural Stewardship Center, the Farm 2000 project, a survey of N-TRAK kit purchasers, and the Iowa Natural Heritage's Resourceful Farming Demonstration Project (RFDP). These programs utilized the late-spring soil test under relatively uncontrolled conditions; hence, there are many limitations in the data. In aggregate, however, these applications demonstrate that the late-spring soil test has been successful overall in both its technical and educational roles. In most cases, the test significantly reduced N rates while maintaining crop yields. In aggregate, on an estimated

30,000 acres, these studies showed N reductions averaging 40-90 lbs-N/acre, with either no yield differences, or small differences of 1-2%. This decrease in purchased N, with little or no decline in yields, indicated that use of the test provided increased profits, ranging from $2 to $16/acre. The Dordt College study alone, indicated a savings to participating producers of $142,000.

The test was most consistent for a corn after corn rotation. The uncontrolled data from the N-TRAK users survey suggests that the use of the test on corn after soybeans decreased profits, but the data are equivocal, at best. Even in the more controlled applications, however, the results for corn following soybeans were more variable. This may have been related to weather conditions in 1989-1990 and, in some cases, to greater than needed N applications even with the test. However, even when the test appeared to fail technically (for corn after soybeans), it was still successful in encouraging most participating farmers to consider reducing N rates and to recognize the need for more closely monitoring N applications in their operations. Such success is highlighted both by the fifteen RFDP participants who felt the test was worthwhile even though they had lower returns with the soil test and the 89% of N-TRAK users who said they would likely continue using the test.

Although the soil nitrate test performed quite well in most of these programs, it must be recognized as only one part of an integrated approach to improved N management. For example, these results showed that the test may need further refinement in accounting for the effects of a previous soybean crop. The soil test data, and the validity of critical test values that cut across various soil and management conditions, illustrate the need to evaluate the concept of yield goals in nutrient planning. Furthermore, as clearly demonstrated by the PFI trials in 1991, soil test results are best used in the context of detailed historical management information that can only be provided by farmers' own knowledge and experience with their fields and adequate record keeping.

Successes with the soil test, continued refinement of soil testing and analysis, and recognition by farmers of the potential savings to be gained by using the test may eventually "mainstream" late-spring soil testing in Iowa. Continuing acceptance of the test will be further stimulated by agribusiness dealers recognizing the economic benefits of providing soil testing services. These data are exemplary of the necessity of this new tool for N-management improvement. The soil-nitrate tests and other tests being calibrated are *not* panaceas, nor foolproof. Continued work will further refine their use and application.

INTRODUCTION

Nitrogen fertilization is essential for profitable corn production in Iowa. Nitrogen is also a major cost of production and, when lost from the cropping system, contributes to environmental problems. Since 1982, the state of Iowa has implemented a large array of programs to improve the environmental performance of agriculture as part of Iowa's Agricultural-Energy-Environmental Initiative. Improved nitrogen management has been one primary objective of the programs because of the extensive regional problems with nitrate contamination of water supplies that has evolved over time in Iowa and other corn-belt states (Hallberg, 1987, 1989; Keeney, 1986; Kross et al., 1993). Nitrogen (N) management was also targeted because assessments of farm management showed clear opportunities to enhance the efficiency and profitability of Iowa farmers through improved N-management (Hallberg et al., 1991).

A consortium of agencies and institutions has been involved in implementing various demonstration, implementation, and education efforts including: the Big Spring Basin Demonstration Project (BSBDP); the Integrated Farm Management Demonstration Project (IFMDP), which initiated or enhanced many innovative projects, including the Integrated Crop Management (ICM) program and the Field Extension Education Laboratory (FEEL); and the Model Farms Demonstration Project (MFDP). The Iowa Groundwater Protection Act (IGWPA) provided support for these programs and also created the Leopold Center for Sustainable Agriculture at Iowa State University, which has organized additional initiatives. Research and development projects were also initiated and supported by these programs. Intensive work began in 1985 to find and calibrate plant tissue tests and a nitrogen soil test as new tools for N management (Blackmer and Morris, 1992). These efforts have been supported by the Iowa Fertilizer and Chemical Association as well as the consortium of public agencies and institutions. This paper reviews the results of uncontrolled farmer and other user applications of the late-spring soil nitrogen test in Iowa as part of various education and demonstration projects.

Background

Optimal rates of N fertilization for corn can vary greatly because of the complex cycling of nitrogen in the soil-plant system. Variability over time and location and the complex interactions of soil properties, weather, and management practices all affect optimal N application rates. Standard recommendations for N use must be based on long-term observations and averages, but the practical factors used, such as soil association, yield goals, and credits for N from previous legume crops or manure can only account for a portion of the variability encountered in a particular field in a particular year. As a result of such uncertainty, nitrogen has often been applied to corn in excess of that needed to produce optimal yields. This excessive use of nitrogen fertilizer represents both an unnecessary input cost for farming operations and a potential source of environmental contamination. To improve N efficiency, reduce N loading into the environment, and preserve crop yields, corn producers need a proven and timely method to determine the amount of N fertilizer to apply.

As noted, in 1985 research efforts were initiated to find a soil test to guide refined fertilizer-N application under Iowa conditions. Efforts have focused on methods for rapid measurement of soil-nitrate concentrations, either in the early spring, to calibrate pre-plant applications, or in late spring, as a pre-sidedress test. While research continues to refine potential early spring test protocols, the late-spring, or pre-sidedress soil test has shown significant potential for refining N management in Iowa and other corn producing areas (e.g., Blackmer et al., 1989; Magdoff, 1991; Bundy and Andraski, 1993). The test procedures have been tailored to Iowa conditions and afford a refined estimate of additional nitrogen needs that can then be sidedressed to the growing crop (Blackmer et al., 1991).

The late-spring soil test, as implemented in Iowa, measures the amount of plant-available nitrate in the surface foot of soil when corn is 6 to 12 inches tall — i.e., in late spring. These procedures are designed to conduct the soil sampling late enough to account for the effects of spring weather conditions yet early enough to allow the producer to

Table 1. Summary of results from 104 on-farm trials comparing farmers' normal rate of fertilization to rates used with the late-spring soil nitrate test (after Blackmer and Morris, 1992).

Year	Mean fertilizer-N rate		Mean corn grain yields	
	Normal	Soil Test	Normal	Soil Test
	lbs-N/acre		bu/acre	
1989	123	48	131	131
1990	131	104	137	137
1991	136	88	145	141
1989-1991	131	85	139	137

sidedress additional N if needed. Testing in fall, or even early spring, is often inaccurate because the wet conditions typical in early spring may remove available nitrate through leaching or denitrification. Such timing may also inadequately account for significant N that is mineralized during the spring, as soil temperatures increase.

The measurement of nitrate concentration in late spring allows the farm operator to sidedress nitrogen at a rate needed to optimize yield. Even if they don't sidedress, the test can also be used by producers to assess their preplant application practices (Blackmer and Morris, 1992). If farmers apply nitrogen at a rate greater than soil test recommendations a potential for loss in profits exists. Such inefficiency in nitrogen application may also result in the contamination of groundwater and surface water or the atmosphere through loss of excess N. Various studies across Iowa show the need for N management refinement. The Butler County Integrated Crop Management Project (Smidt et al., 1991), the Big Spring Basin Demonstration Project, and statewide surveys using the soil test between 1987 and 1991 have often shown that over 50% of corn fields surveyed exhibit soil nitrate concentrations at, or *greater than* the critical concentration needed for optimal corn yields (Blackmer and Morris, 1992).

The soil test is now in use by many farmers and crop consultants. The standard procedures for appropriate use of the test are covered in publications issued by Iowa State University Extension and the Leopold Center (e.g., ISU Extension Publication PM-1521, Blackmer et al., 1993); these bulletins are updated as further refinements of the test are made.

Various reports have documented the calibration and successful application of the soil test program (e.g., Blackmer and Morris, 1992; Killorn, Voss, and Hornstein, 1992; Hallberg et al., 1991). For example, replicated on-farm implementation of the test during 1989-1991, collaboratively between farmers, Iowa State University, and fertilizer dealers, showed that the use of the soil test enabled many producers to reduce fertilizer inputs by 33% with negligible reductions in corn yields; in two of three years there was no difference in yields (Table 1). The use of the test was profitable in all three years, across a range of corn and nitrogen prices (Blackmer, 1993). These results were impressive and surprising because: 1) the soil test was new and is being improved; 2) the normal rates of N used by the farmers involved were quite conservative compared to the norm; and 3) 1990 and 1991 had wet spring weather, and the expectation was that the test would suggest an increased need for added N. Such reductions of N translate to increased profits for farmers; they also reduce environmental problems and reduce the consumption of nonrenewable fossil fuels needed to manufacture nitrogen.

The soil test also has been put into use on a broader scale, beyond these carefully planned calibration and implementation studies. The intent of this report is to review and summarize the performance of the late-spring soil nitrate test as employed in various other uncontrolled local and statewide applications: 1) as part of the continuing evaluation of Iowa's Agricultural-Energy-Environmental Initiative; and 2) to assess any problems apparent in the early, uncontrolled use of the test.

PROJECT SUMMARIES

Results from various projects that made use of the late-spring soil test are summarized below. To examine and compare results from the various projects, standard values of $0.15/lb for nitrogen fertilizer and $2.25/bushel corn were used; corn yields were adjusted to 15.5% moisture, unless otherwise noted (Hallberg et al., 1991). Differences in "profit" or "losses" from the use of the soil test are based only on the resultant fertilizer nitrogen use and corn yield values. Other factors, such as application or labor costs, land or equipment charges for a particular farm, are not included, and are beyond the scope of this report.

Practical Farmers of Iowa

Practical Farmers of Iowa (PFI) is a non-profit, educational organization, comprised primarily of practicing farmers throughout the state. Their aim is to conduct on-farm demonstrations of profitable, environmentally sound farming methods. PFI uses cooperators' farms as teaching tools to demonstrate sustainable farming and to promote replicated trials as a problem solving approach that farmers can use operationally.

From 1987 to 1989, PFI organized and coordinated thirty-five on-farm trials utilizing the late-spring soil nitrate test to gauge nitrogen needs. These efforts were supported, in part, by the Integrated Farm Management Demonstration Project, through the Iowa Department of Agriculture and Land Stewardship, Iowa State University Extension, and the Leopold Center. These replicated trials consisted of full-width strip plots, usually eight rows wide, extending the length of a field. They provided side-by-side comparisons of the efficiency of nitrogen rates based upon soil test recommendations with farmers' typical nitrogen management. Over these three years, participants found no difference in yields by using the soil test while applying an average fifty-five pounds less nitrogen per acre than their customary rate (Exner, 1991).

PFI also conducted fourteen trials involving the soil test in 1990. With heavy rainfall in the spring of that year, the soil test recommendations were higher than for the previous three years. Nevertheless, use of the soil test reduced nitrogen application by an average of 46 lbs/acre with a yield reduction of 1.3 bushels per acre. This amounted to an average savings of $6.12 per acre by using the soil test (Exner, 1991).

PFI continued soil test trials in 1991. Nine cooperators continued demonstrations comparing the performance of a low rate and a high rate of nitrogen. Several of the participants based their higher N rate on soil test recommendations. However, the lower rate produced an average savings of $10.69 per acre compared to this higher rate. This result demonstrates that the soil test recommendations can be further adjusted and refined by farmers' own knowledge of their fields (Exner, 1992).

Dordt College

The Dordt College Agricultural Stewardship Center (ASC), a farming-teaching-research facility, is located in Sioux Center, in northwest Iowa. Northwest Iowa is a major livestock enterprise area, with substantial manure resources and relatively large acreages of corn in rotation with alfalfa. Adequate nitrogen credit is often not given for manure and alfalfa before application of fertilizer N, resulting in over-application. In such areas, nitrogen management can be significantly improved, enhancing profitability for area farmers.

The ASC made use of the late-spring soil nitrate test in a project conducted from May 1988 to July 1991, through grant support from the Leopold

Center. This project was aimed at understanding the fate of nitrogen and improving on-farm management of nitrogen fertilizers. In 1989, five area farm operators and crop consultants used the soil test on a total of 8,722 acres. No difference in yield was found by using the soil test recommendations compared to adjacent fields under typical nitrogen management, and an average savings of $16.24 per acre was realized. This amounted to a total estimated savings to area farmers of approximately $142,000. Follow up surveys of local farmers show that they have continued to expand the acreage on which they are applying the soil nitrate test (Vander Zee, Vos, and Goedhart, 1991, 1992).

Farm 2000

The Farm 2000 Project, centered in Poweshiek County, is an innovative local program initiative, initially supported by the Integrated Farm Management Demonstration Program, ISU Extension, and the Grinnell 2000 Foundation (e.g., Grundman and Hopkins, 1992). The goal of the project was to provide farmers with the improved skills and tools they need to make effective decisions in implementing sustainable agricultural practices. Farm 2000 was designed to: 1) transfer research findings and technology into production practices; 2) reduce reliance on external purchased inputs; and 3) increase local self-reliance through development of local leadership potential (Grundman and Hopkins, 1991).

In 1989, eight Farm 2000 cooperators used the late spring soil test. This soil testing resulted in increased profits for the farmers of $7,794 (Hopkins, 1989b). The soil tests showed that corn after alfalfa needed no additional nitrogen, which is not unusual, but corn following corn also required *no additional* N. Dry weather and poor yields in 1988 resulted in significant N carryover. In contrast, corn following soybeans needed a significant rate of N sidedressed. This additional N demand was attributed to the likelihood that drought-stress of soybeans in 1988 resulted in reduced nitrogen fixation (Hopkins, 1989 a,b).

N-TRAK Purchasers

Beginning in 1990, the late-spring soil nitrate test was made available to the public as "N-TRAK" kits manufactured by Hach Company. The N-TRAK kit provided farm operators or crop advisors with "do-it-yourself" technology to perform convenient on-farm soil testing and analysis. The kit included instructions on how to take and prepare the samples, as well as how to conduct the test. However, how accurately the instructions were followed, and how adequately the test was applied is not known. In addition, in contrast to the three projects reviewed above (PFI, Dordt College, and Farm 2000), this application of the soil test had no trained staff involved to guide soil sampling, testing, or use of the results. The use of the N-TRAK kits was totally uncontrolled and results from these applications must be viewed with this perspective. Further, the winter and spring of 1990 were also quite wet, making the timing of soil test use, and its interpretation difficult even in controlled settings.

To understand farmers' perceptions of the compatibility of the test to their operations and to assess any economic costs or benefits of test application, a survey of 600 N-TRAK purchasers was conducted in July of 1990 (Contant and Korsching, 1993). In December, 1990, a follow-up questionnaire was sent to respondents of the initial survey. Both surveys queried respondents on farm and farm operator characteristics, use of the kit and how it performed, and N rates and yields with and without the test. Of the 600 purchasers originally surveyed, 299 returned completed questionnaires. Approximately 67% (200) of these respondents indicated that they had actually used the test.

The N-TRAK kit was used on at least 357 fields. Participants reported some comparison data for 71 fields, where typical rates of nitrogen were applied. Results for different rotations were mixed. In aggregate, use of the N-TRAK kit showed an average loss of approximately $11/acre in relation to the comparison fields. For corn following a soybean crop, this review suggests participants experienced an average loss by using the kit of approximately $29/acre. Use of N-TRAK recommendations with corn after corn, however, achieved a $7/acre savings over the comparison fields.

From the original information, only 36 complete pairwise comparisons could be deduced for the analysis in this report. The pairwise comparisons mirrored the aggregate patterns. In total, fields getting N rates based upon N-TRAK analysis showed a $10/acre loss in comparison to fields receiving farmers' usual application rates. Test fields for corn following corn saved approximately $2/acre over comparison fields, while test fields with the previous crop soybeans lost $15 per acre.

Although these data seem to imply that the N-TRAK kit was ineffective in maintaining yields and profits while reducing nitrogen use, at least for corn following soybeans, the majority of respondents felt that their expectations of the test had been met. When asked what expectations they had of the N-TRAK kit for their farming operations, 26% of the test users indicated that they hoped the test would lower nitrogen costs, while 55% felt the test would more precisely determine the amount of fertilizer actually needed (most likely this expectation is also related to a desire to lower input costs while maximizing yields). Only 7% of the kit users expected application of the test to reduce the environmental impact of farm chemicals.

In the follow-up survey, after harvest of that year's crop, when asked if their expectations were met, 60% of 160 kit users responded yes, while 35% indicated that their expectations for the N-TRAK kit were not met. This seeming contradiction between the N rate and yield data and participants' comments may result from problems in the self reporting of data and a lack of quality control. In other words, there was no way to guarantee that test and comparison fields were closely matched or that the data were collected and reported correctly. Because of differences in the comparison fields, the resultant yields may not have been expected to be comparable. The yields reported were not likely corrected (standardized) for differences in moisture content. Such uncorrected yield data make it difficult to interpret the data, as well. Further, it was impossible to ascertain if N rates applied followed the test results and guidelines, or what the producers goals may have been with the reduced application rates. Even with these uncertainties, 89% of respondents said they would definitely or probably use the kit again in 1991.

Comparison of Soil-Test Kit and Laboratory Results

One of the reasons for development of the N-TRAK soil-test kit was the concern for timely soil testing and analysis. Could soil tests be taken at the correct time, shipped to a laboratory, analyzed, and the results returned to the farmer in time to allow necessary sidedressing? The use of the test kit on the farm could alleviate such concerns. However, as discussed above, there are also concerns with use of the on-farm test, such as the clarity of the directions for sampling, running the analysis, potential "operator" error, and the accuracy of the results, particularly in comparison to laboratory analyses that are conducted under more controlled conditions and quality control.

Morris and Blackmer (1988), from Iowa State University, conducted a study with 25 farmers, to assess the comparability of N soil-test results produced by farmers, using a prototype of the N-TRAK kit, with standard laboratory analyses. The farmers collected, dried, and crushed the soil samples; mixed and split the samples, analyzing one according to the kit directions, and sending the other to the ISU research team. No statistically significant difference was found between the on-farm and laboratory analyses, when soil nitrate concentrations were less than 30 ppm (mg nitrate-N/L). There was some loss in accuracy when soil nitrate concentrations were >30 mg/L. This is a minor problem because the optimal range in soil nitrate concentration for corn production is 21 to 25 ppm (mg nitrate-N/L). Though some outliers, and aberrant values occurred, the replicate sampling called for in the directions should reveal these. The study concluded that with slight modifications in soil testing instructions and procedures, most farmers can analyze soil samples on their own with the accuracy needed to improve current fertilization practices. (These modifications were incorporated in the N-TRAK kit that is being sold commercially.) As noted in the prior discussions, however, in uncontrolled studies there is no way to ensure that kit operators strictly follow the directions.

Resourceful Farming Demonstration Project

The Iowa Natural Heritage Foundation conducted the Resourceful Farming Demonstration Project (Sand, 1987; Contant, 1988) during 1987-1989, as part of the Integrated Farm Management Demonstration Project. In 1989, this project involved 144 Iowa farmers testing and demonstrating conservation tillage, improved fertilizer efficiency, and reduced pesticide and herbicide use, generally in collaboration with private crop advisors, often from local agribusiness dealerships. This project attempted to offer farmers a way to experiment with more environmentally sound techniques while sharing their experiences with other farmers.

In 1989, at least sixty-seven of these farmers used the late-spring soil nitrate test to assess the amount of nitrogen fertilizer needed for their corn crops. More may have used the test but from the way the data were reported it is uncertain. Only those participants who explicitly referred to sidedressing nitrogen, at a rate based upon the soil test, were included in this analysis. In addition, ten farmers' results were excluded from this analysis because of excessively low yields for demonstration and comparison trials. The drought of 1988 and 1989 likely was the cause of these greatly reduced yields. Another farmer's results were removed because his crop consultant cited the likelihood of lab error. Consequently, this analysis examines fifty-six farmers' experiences with utilizing the soil test. These demonstrations were located in forty-three counties throughout Iowa.

Demonstration and comparison "plots" were established to evaluate the effectiveness of the soil nitrate test in defining more efficient rates of nitrogen to apply for optimal crop yields. "Plot" size ranged from unspecified to tens of acres. Nitrogen needs of the demonstration plots were assessed through the soil test, while the comparison plots were under the farmers' typical management. Some farmers conducted multiple comparisons. In total, there was some information available on seventy demonstrations that compared corn yields with and without application of the soil nitrate test recommendations.

Project Weaknesses

The project design called for the demonstration and comparison plots to be matched, as closely as possible, with regard to size, soil type, slope, and other nutrients and pesticides applied. This was not always done; some sites were in different fields; some sites had different pest management used, some apparently had differential manure applications, and for many the other treatments were not clear. There are a number of other variables that were not always reported that may have affected the results, including weather conditions, manure application, residual nitrogen, and previous crop. Potentially, the most influential among these is the amount of residual nitrogen in the two plots. The quantitative results of the soil test were listed for only sixteen of the demonstration plots. Of those sixteen, only eight also listed the nitrate content of the comparison plot. It is impossible, therefore, to establish what, if any, effect differences in residual nitrogen between the two plots had on crop yields and savings. Furthermore, without soil nitrate results for the demonstration plots, it is difficult to conclude how many farmers actually followed the recommendations of the soil test. For example, on at least three demonstration plots, farmers sidedressed in excess of the soil test recommendations, clearly affecting the analysis of results.

Also unclear from the reported results is how many participants applied manure to their fields. For only twelve of the demonstrations was manure usage explicitly reported. More problematic, however, is that for the farmers applying manure to their fields many failed to credit the nitrogen content. Other surveys have shown that Iowa farmers routinely fail to appropriately credit livestock manures (Hallberg, et al. 1991). This omission prevents a complete accounting of the nitrogen applied to the plots. In addition, in some cases the previous crop was not clear.

The original yield data reported by the project were not corrected for moisture contents. Wherever the moisture contents were reported the data were corrected and standardized. Finally, soil sampling was performed, presumably, by the private crop advisors, collaborating in the project, and it is impossible to verify if the sampling was done properly for this new procedure. It is also impossible to assess whether the resultant recommendations followed appropriate guidelines, and as noted, whether the recommendations were followed. Although analysis of results and confidence in the data are limited in these ways, the Resourceful Farming Demonstration Project provides knowledge of the soil nitrate test to farmers and insights into its use under these relatively uncontrolled, operational conditions.

Project Results

Of the seventy demonstrations, forty-nine (70%) either showed no difference in profits or accrued greater profits than the comparison plots with reduced N and the use of the soil test. The remaining twenty-one (30%) demonstrations, therefore, earned less profit than the comparison plots. The results for all sites are summarized in Table 2. For those fields using the soil nitrate test, the average corn yield was 143 bushels/acre with an average application rate of 76 pounds of nitrogen fertilizer per acre. The comparison fields, under the farmers' normal management, produced an average yield of 144 bu/acre with 141 lbs-N/acre. Therefore, an increased N application of 65 lbs-N/acre only showed an average yield increase of about one bushel per acre. These results translate into an average overall savings of $5.75 per acre using the soil nitrate test over the standard management system. There was substantial variability in the results, however. The largest savings shown was $46/acre, while the greatest loss shown by the demonstrations (with soil test recommendations) was approximately $53/acre.

The fertilizer-nitrogen rate distributions, shown in Figures 1 and 2, illustrate the significant differences between the soil test recommendations and the farmers' normal rate of N. Figures 3 and 4 illustrate the relatively small, nonsignificant differences in yields between the demonstration and comparison plots. These demonstrate the potential for improvement in nitrogen management that can be accomplished. Frequency distributions of the differences of nitrogen rates, yields, and estimated profits are presented in Figures 5, 6, and 7. These distributions illustrate most clearly the potential for Iowa farmers to refine their fertilization practices to minimize surface and groundwater contamination, while maintaining crop yields and enhancing profits.

Table 2. Summary of results from 70 Resourceful Farming demonstrations using the nitrogen soil test.

Fertilizer Treatment	Mean nitrogen rate	Mean corn grain yield
	lbs-N/acre	bu/acre
Normal/Comparison System:		
At farmer's normal nitrogen rate;	141	144
Demonstration System:		
Using the nitrogen soil test;	76	143
Difference:	**65**	**1**

The difference in nitrogen application rates was pronounced in the study year as a result of significant nitrogen carryover from dry weather and reduced yields in 1988 and the dry spring in 1989. In the RFDP, dry weather was noted in comments from 40% of the demonstrations, and in 16% of the cases dry and drought conditions were specifically cited as the reason for less nitrogen needed. In spite of the note of drought conditions, the corn yields reported for these sites were greater (Table 2) than the statewide average of 118 bu/acre recorded by the National Agricultural Statistical Service. The statewide average nitrogen rate for corn was also substantially less than the RFDP sites, at 128 lbs-N/acre.

Previous Crop

Examining the RFDP reports in terms of the

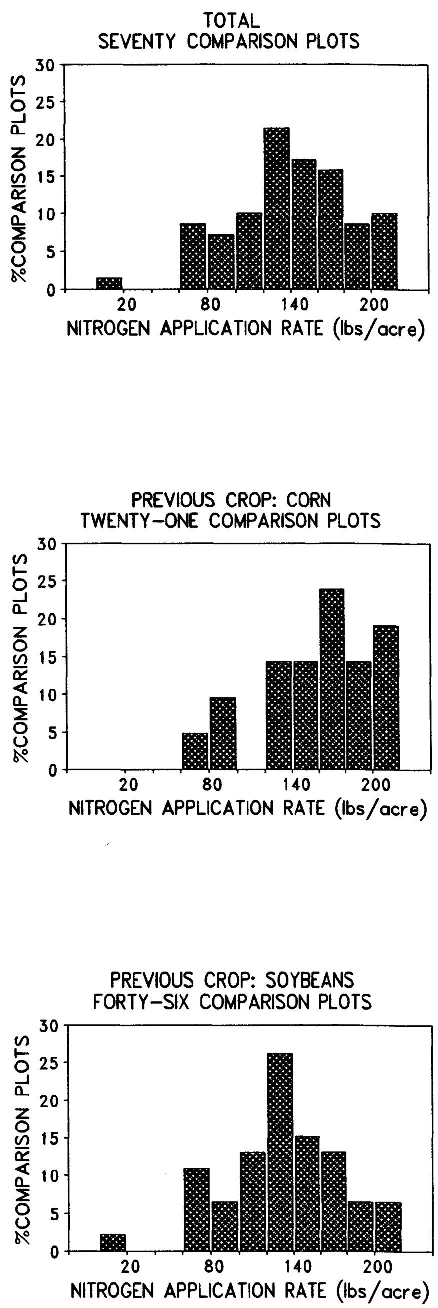

Figure 1. Frequency distributions of farmers' typical nitrogen fertilizer rates for all sites and separately by previous crop, for RFDP comparisons.

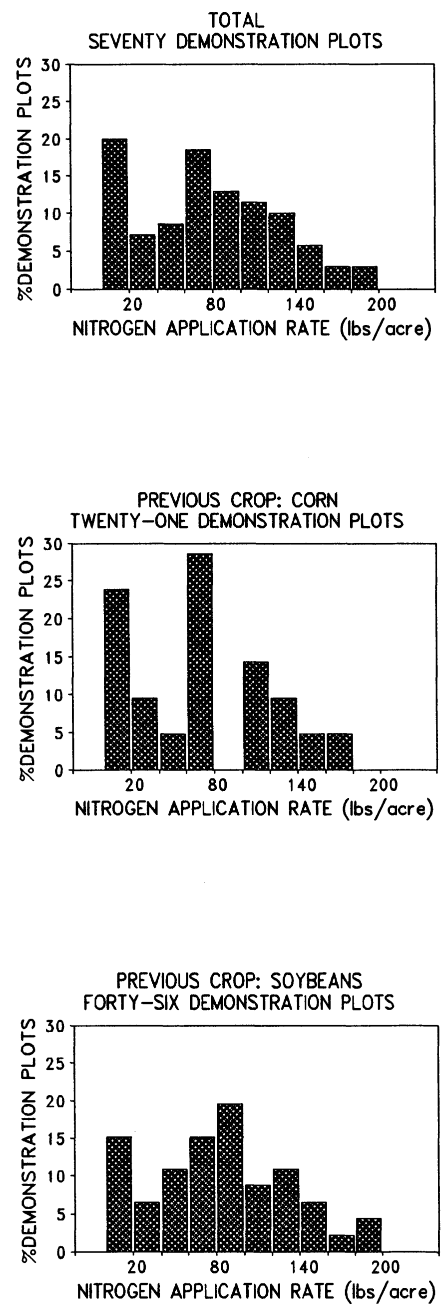

Figure 2. Frequency distributions of nitrogen fertilizer rates based upon soil test recommendations for all sites and separately by previous crop, for RFDP comparisons.

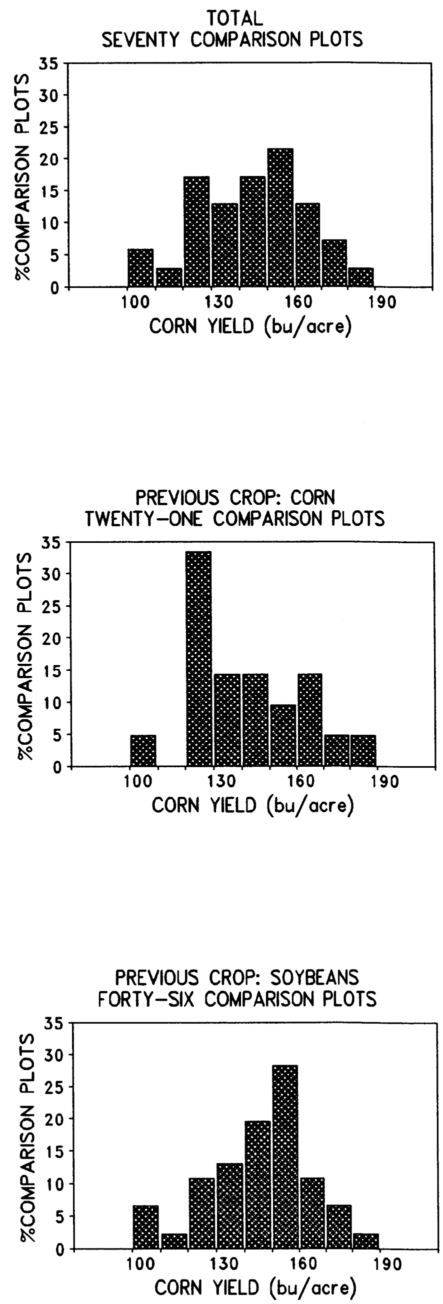

Figure 3. Frequency distributions of RFDP participants' corn yields using typical nitrogen fertilizer rates, for all sites and separately by previous crop.

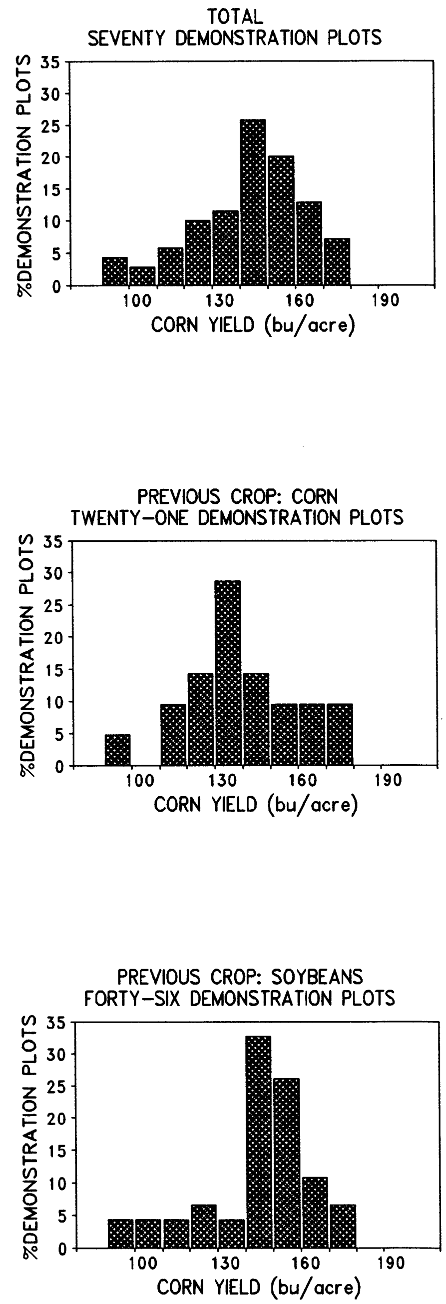

Figure 4. Frequency distributions of RFDP participants' corn yields with nitrogen rates based upon soil test recommendations, for all sites and separately by previous crop.

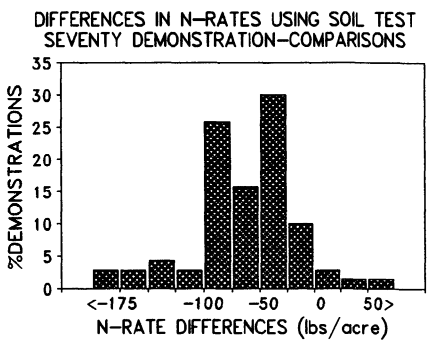

Figure 5. Frequency distribution of the differences between demonstration and comparison plots in the rate of N applied (demonstration minus comparison), for RFDP comparisons.

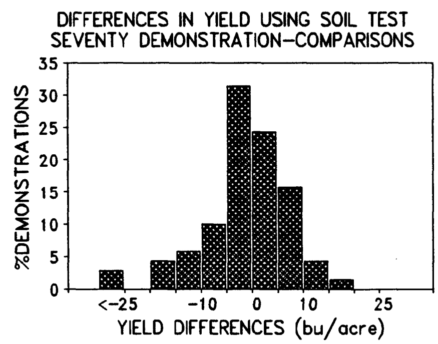

Figure 6. Frequency distribution of the yield differences between the demonstration and comparison plots (demonstration minus comparison), for RFDP comparisons.

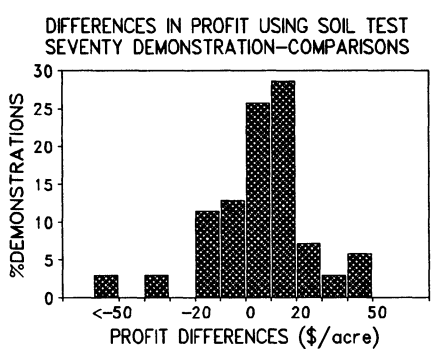

Figure 7. Frequency distribution of the profit differences between the demonstration and comparison plots (demonstration minus comparison), for RFDP comparisons.

previous crop provides a number of important insights. Of the seventy sites, 30% (21) were corn following corn, 65% (46) were corn after soybeans, 3% (2) were corn after meadow, and 1% (1) was corn after oats. With corn following corn, there was an average savings of $8.83/acre using the soil test; 81% (17) of these demonstration sites achieved greater profits than the plots under the farmers' typical management. In contrast, using the soil test with corn following soybeans achieved a savings of $3.71/acre, with 65% (30 sites) of the demonstrations saving money over the comparison plots. With either corn or soybeans as the previous crop, the average comparison yield was approximately two bushels greater per acre than the soil test demonstration. The mean difference in savings, therefore, can be attributed to the difference between the nitrogen rates with and without the test.

The average nitrogen rate with the test was 71 lbs/acre for corn following corn and 81 lbs/acre for corn after soybeans. The average rate without the test was 160 lbs-N/acre for corn after corn and 132 lbs/acre for corn following soybeans. With corn after corn, therefore, comparison plots were receiving on average 89 lbs/acre more nitrogen than needed, according to the test and resultant yields, while comparison plots with corn following soybeans were getting an excess of 51 lbs-N/acre (Tables 3 and 4; Figures 1 and 2). While still applying more N than the soil test indicates as necessary, most farmers planting corn after soybeans seem to be more accurately predicting their nitrogen requirements, by taking credits for their previous soybean crop. A number of surveys in Iowa reinforce this conclusion with 75% to 80% of farmers reporting that they credit a previous crop of soybeans with an average 35 lbs-N/acre (Hallberg, et al. 1991).

Farmers' Comments

Most of the farmers participating in the RFDP project responded favorably to the results of the soil nitrate test. Of the seventy demonstrations, 79% of farmers (55) commented positively about the soil test correctly predicting nitrogen needs. On only five (7%) of the demonstrations, did participants

Table 3. Summary of results from 21 Resourceful Farming demonstrations using the nitrogen soil test for corn following corn.

Fertilizer Treatment	Mean nitrogen rate	Mean corn grain yield
	lbs-N/acre	bu/acre
Normal/Comparison System:		
At farmer's normal nitrogen rate;	160	142
Demonstration System:		
Using the nitrogen soil test;	71	140
Difference:	**89**	**2**

Table 4. Summary of results from 46 Resourceful Farming demonstrations using the nitrogen soil test for corn following soybeans.

Fertilizer Treatment	Mean nitrogen rate	Mean corn grain yield
	lbs-N/acre	bu/acre
Normal/Comparison System:		
At farmer's normal nitrogen rate;	141	144
Demonstration System:		
Using the nitrogen soil test;	76	143
Difference:	**65**	**2***

* 2 bushel difference with rounding.

express doubts about the validity of the test and feel that the additional nitrogen applied on the comparison plots significantly improved yields. These five cases all showed a loss in profits by using the soil test recommendations compared to normal rates of N fertilizer applied. However, of the remaining 16 demonstrations that showed less profit than the comparison plots, 15 farmers still commented positively on the soil nitrate test. One farmer, who lost an estimated $53 per acre (per the calculations used here) on his demonstration compared to using his normal N rate, noted that the "...nitrate test seemed a good starting point, [yet] it is difficult to know what yield goal to set." Participants generally felt the test was worthwhile and that it correctly predicted the amount of nitrogen to apply for the yield goal chosen. They did, however, express a desire to have the soil nitrate test and the process to determine yield goals further refined. In thirteen (19%) of the demonstrations, farmers said they would continue such soil testing in the future.

SOIL TEST USE FOR CORN AFTER SOYBEANS

Review of these various programs confirm the general efficacy of the late-spring soil nitrate test, particularly for corn following corn. However, the results for corn following soybeans were much more variable, at least for the conditions of these programs in 1989 and 1990.

Of the twenty-one demonstrations in the RFDP that showed less profit by following soil test recommendations, sixteen (76%) were for corn following soybeans. For corn following corn, over 80% of trials showed increased profits, but only 65% of corn after soybean trials were positive. In addition, the average nitrogen rate applied using the soil nitrate test was higher for corn following soybeans than for corn after corn (see Tables 3 and 4). In 1989, in the Farm 2000 program, soil tests and resultant yields showed that corn after alfalfa and corn after corn needed no additional nitrogen. Dry weather and poor yields in 1988 resulted in significant N carryover. Yet, corn following soybeans apparently needed a significant rate of N sidedressed. In the uncontrolled use of the N-TRAK test kit users, corn following corn showed positive economic returns, yet, on average corn following soybeans exhibited a loss.

Corn following soybeans nearly always produces greater yields than continuous corn. This is often attributed to nitrogen fixation by the leguminous soybeans. However, under midwest conditions some studies suggest that soybeans may remove more nitrogen than they fix, possibly resulting in a net N deficit (e.g., Schepers and Mosier, 1991). This suggests that much of the corn yield increase may be attributed to "rotation effects" other than N fixation. The N value attributed to soybeans is better termed as the N fertilizer replacement value (or N "credit").

As noted, some of the programs attributed the variability of results, and the greater N called for by the soil test with corn after soybeans, to the likelihood that drought-stress of soybeans resulted in reduced nitrogen fixation. This may be part of what the test values were reflecting under the abnormal weather conditions during 1989-1990. Some economic losses appeared related to more N being used than needed, as well. The greater variability recorded suggests that some refinement of test procedures and interpretations may be needed for corn after soybeans. Research and calibration studies have continued to review this.

CONCLUSIONS

The late-spring soil nitrate test has several roles in making Iowa agriculture more efficient and sustainable. It is a technical tool that can reduce inefficient nitrogen fertilizer use, while maintaining yields, and as a consequence improve profitability, as well as water quality by reducing N loading. It can also be used as a feedback tool, even when producers are not sidedressing N. In this sense, as well as the general reporting of results to the farm sector, it provides an educational tool giving Iowa farmers greater insight into N fertilizer use and the factors that affect fertilization needs. These various roles all must be emphasized if efficient, long term reductions in the application rates of nitrogen are to be achieved.

The several programs discussed in this report, utilized the late-spring soil test under relatively uncontrolled conditions. In aggregate, these programs applied the soil test on an estimated 30,000 acres, or more. The Dordt College study alone indicated a savings to participating producers of $142,000. The programs examined demonstrate that the late-spring soil test has been successful overall in both its technical and educational roles. In most cases, the test has significantly reduced N rates while maintaining crop yields. In aggregate, these studies showed N reductions averaging 40-90 lbs-N/acre, with either no yield differences, or small differences of 1-2%. The resultant of the decrease in purchased N, with little or no decline in yields, indicated that use of the test provided increased profits, ranging from $2 to $16/acre. The test was most consistent for corn after corn. The uncontrolled data from the N-TRAK users survey suggested that the use of the test on corn after soybeans decreased profits, but the data are equivocal at best. However, even when the test appears to fail technically, as was the case in the N-TRAK survey and some of the RFDP comparisons, it was still successful in encouraging most participating farmers to consider reducing N rates and to recognize the need and potential of the soil nitrate test for their operations. Such success is highlighted by the fifteen RFDP participants who had lower returns with the soil test yet still felt the test was worthwhile and the 89% of N-TRAK users who said they would likely continue using the test.

Although the soil nitrate test performed quite well in most of these programs, it must be recognized as only one part of an approach to improved N management. These programs showed that the test, or its interpretation and recommendations, may need further refinement in accounting for the effects of a previous soybean crop. The soil test data, and the validity of critical test values that cut across various soil and management conditions, illustrate the need to evaluate the concept of yield goals in nutrient planning. Furthermore, as clearly demonstrated by the PFI trials in 1991, soil test results are best used in the context of detailed historical management information that can only be provided by farmers' own knowledge of, and experience with their fields, and adequate record keeping.

Successes with the soil test, like those described above, continuing refinement of soil testing and analysis, and recognition by farmers of the potential savings to be gained by using the test will eventually "mainstream" late-spring soil testing in Iowa. Continuing acceptance of the test will be further stimulated by agricultural chemical dealers recognizing the economic benefits of providing soil testing services. These data are exemplary of the necessity of this new tool for N-management improvement. The soil-nitrate tests and other tests being calibrated are *not* panaceas, nor foolproof, and work continues to refine their application.

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