Project Title:

On-farm Evaluation Partnership to implement enhanced efficiency fertilizer trials using a new scientific protocol and an adaptive management approach.

Grantee: Brookside Laboratories, Inc.

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Project Summary

The goal of this project was to implement field-scale trials to evaluate enhanced efficiency fertilizers (EEFs). Enhanced efficiency fertilizers when used properly can improve nitrogen management and reduce environmentally harmful nitrogen losses to air and water. Farmers were interested in evaluating new or re-formulated EEFs such as Instinct NXTGEN, Centuro, Anvol, and BD-Ntrust, to learn if these products would benefit their operations. Farmers were also interested in evaluating an older EEF, N-Serve.

Results from the 72 field-scale trials evaluating three nitrification inhibitors, N-Serve, Instinct NXTGEN, and Centuro completed from 2020 to 2022 across the Corn Belt showed an average loss of $12.89 per acre when these EEFs were added to the Farmer Normal sidedress rate of nitrogen application. When these EEFs were added to a rate of sidedress nitrogen that was 50 or 75% of the Farmer's Normal rate of sidedress the loss was $18.50 per acre.

Results from the 51 trials evaluating BD-Ntrust, which is an EEF designed to work with applied liquid nitrogen fertilizers to maximize availability and utilization of nitrogen, showed a loss of $8.00 per acre when added to the Farmer Normal sidedress rate of nitrogen. When BD-Ntrust was added to a rate of sidedress nitrogen that was 50 or 75% of the Farmer's Normal rate of sidedress nitrogen the loss was $42.50 per acre.

The most likely reason for the unprofitability of the EEFs was insufficient rainfall. Only 19% of the trials had rainfall greater than 150% of normal. The average percentage of normal rainfall for the trials was only 113% of normal. These EEFs are designed to protect ammonium-based fertilizers from loss due to high rainfall or to enhance nitrogen availability. High rainfall can push the fertilizer below the root zone, called leaching, and can cause loss of the fertilizer as nitrous oxide gas to the atmosphere, called denitrification. A greater amount of rainfall must have been needed across these trials to make the EEFs profitable.

Project Goal and Objectives

The project staff set out to achieve the following goals and objectives through the On-farm Evaluation Partnership to implement enhanced efficiency fertilizer trials using a new scientific protocol and an adaptive management approach project.

1. Establish a locally driven, expert-supported On-Farm Evaluation Partnership combined with an adaptive nutrient management approach by carrying out a total of 150 on-farm trials testing EEFs over three planting seasons with 20 crop advisors and 50 farmers across 4 states.
2. Document and evaluate the environmental, economic, social, and production impacts of the adaptive management process used by the On-Farm Evaluation Partnership.
3. Document the environmental and economic impacts of EEFs for farmers with a variety of soils, climates, farm operations, and practices.
4. Work with NRCS and other partners to develop and disseminate training, field days, and educational materials to facilitate the transfer of the On-Farm Evaluation Partnership model to other areas.

Project Background

The project staff set out to learn why only 13.3% of total nitrogen sales in 2017 were accompanied by an EEF. The technology behind EEFs has been proven in the laboratory to slow the conversion of ammonium to nitrate, which should reduce losses of nitrogen, or to enhance nitrogen availability, which should keep more nitrogen in the root zone. However, when EEFs are tested at a field level, rainfall timing and amount will be the primary drivers of whether the EEFs are profitable.

Enhanced efficiency fertilizers have been tested in small-plot trials as reported in an extensive meta-analysis on our NutrientStar website at: https://nutrientstar.org/tool-finder/. This summary of the results of 812 small-plot trials to evaluate EEFs sold in the US reported changes in yield ranging from minus 11% to plus 9% with most of the trials completed since 2000. It is extremely difficult to interpret the results from these small-plot trials, however, because the timing and amount of rainfall during the trials was rarely reported.

The agricultural consultants and farmers who are members of our project team also had another concern about the small-plot trials reported in the NutrientStar database. They do not think small-plot trials provide a good evaluation of EEFs, and they wanted new and old EEFs to be evaluated by trials that better represented the field conditions on their farms and this meant evaluation by field-scale replicated trials.

Project Methods:

This project used field-scale replicated strip trials to evaluate EEFs. Field-scale evaluation trials are trials with individual plots the width of two passes of the harvest equipment and 600 feet or more in length. The length was typically the length of a field (1,500 feet or more). All trials in this project were longer than 600 feet, and the average trial area was 20 acres. All methods followed the guidelines in Chapman et al. (2016) and Kyveryga et al. (2015).

The comparisons or treatments used to evaluate the EEFs were:

1. The Farmers Normal rate of sidedress nitrogen fertilizer.
2. The Farmers Normal rate of sidedress nitrogen fertilizer with an EEF.
3. 75% of the Farmers Normal rate of sidedress nitrogen fertilizer.
4. 75% of the Farmers Normal rate of sidedress nitrogen fertilizer with an EEF.
5. 50% of the Farmers Normal rate of sidedress nitrogen fertilizer.
6. 50% of the Farmers Normal rate of sidedress nitrogen fertilizer with an EEF.

Most of the trials had four replications of four comparisons for a total of 16 strips. A few trials had three replications. The 75% of the Farmer Normal rate of nitrogen comparison without an EEF was not applied in 2020. The 50% comparisons were completed on only 11 trials in 2022. The average Farmer Normal sidedress nitrogen rate for the trials was 141 pounds per acre and the total nitrogen rate was 206 pounds nitrogen per acre, which included preplant and at-planting nitrogen. See below for an example of a trial layout.

	Rep 1				Rep 2				Rep 3				Rep 4			
Strip No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Buffer Area	T2: Farmer Normal w/ Stabilizer	T1: Farmer Normal Rate	T3: 50% of Farmer Normal Rate w/ Stabilizer	T4: 50% Farmer Normal Rate	T3: 50% of Farmer Normal Rate w/ Stabilizer	T4: 50% Farmer Normal Rate	T2: Farmer Normal w/ Stabilizer	T1: Farmer Normal Rate	T4: 50% Farmer Normal Rate	T2: Farmer Normal w/ Stabilizer	T1: Farmer Normal Rate	T3: 50% of Farmer Normal Rate w/ Stabilizer	T1: Farmer Normal Rate	T3: 50% of Farmer Normal Rate w/ Stabilizer	T4: 50% Farmer Normal Rate	T2: Farmer Normal w/ Stabilizer

Project Results

We report results from the project against our specific project objectives shown in italics.

Objective 1.

Establish a locally driven, expert-supported On-Farm Evaluation Partnership combined with an adaptive nutrient management approach by carrying out a total of 150 on-farm trials testing EEFs over three planting seasons with 20 crop advisors and 50 farmers across 4 states.

The partnership we established consisted of 21 agricultural consultants and 35 farmers across 7 states. Most of the consultants had run field-scale replicated and randomized trials in the past, but both the experienced and inexperienced consultants were trained to perform field-scale replicated and randomized trials. Each consultant worked with one to three farmers over three years to implement 150 evaluation trials of an EEF of interest to the farmer. The EEFs chosen by the farmers were:

1. N-Serve, a nitrification inhibitor from Corteva
2. Instinct NXTGEN, a nitrification inhibitor from Corteva
3. Centuro, a nitrification inhibitor from Koch Agronomic Services
4. BD-Ntrust, a biological product from Biodyne sold as an EEF to enhance nitrogen management.
5. Anvol, a urease inhibitor from Koch Agronomic Services.

Usable yield results were obtained from 123 trials. Some of the trials were not harvested for various reasons such as uncertainty about which strip had the EEF applied, flooding of part of the trial area, and combine yield monitors not being set to capture accurate yield weights. The results from 19 trials evaluating the urease inhibitor Anvol were not used due to improper application of the Anvol. The Anvol was applied below the soil surface instead of on the soil surface. We think this occurred because urease inhibitors are not commonly used on corn in the Corn Belt, and the information from companies that sell urease inhibitors does not explicitly state that their products should be applied only to the soil surface. Instead, the products are advertised to reduce ammonia volatilization, which is a term that many consultants and farmers are not familiar with. If NRCS plans to provide incentive payments for urease inhibitors, explicit instructions about how to apply the inhibitors should be included for the farmers and NRCS employees involved in the incentive program.

Thirty-five farmers instead of 50 established trials and the lower number is the result of some farmers establishing more than one trial on their farm. We did exceed our objective of establishing trials in 5 states by establishing them in seven states: IA, IL, IN, OH, MI, MO, and NC. And 21 consultants participated in the program, which is one more than our objective.

Objective 2.

Document and evaluate the environmental, economic, social, and production impacts of the adaptive management process used by the On-Farm Evaluation Partnership.

Adaptive management is a process by which farmers and their advisors collect, monitor, analyze, and learn from the results of on-farm field-scale evaluations. The evaluations produce results that inform the adaptive management cycle where farmers and advisors assess the results through discussions. Farmers and advisors can then work together to adjust practices according to what they learn.

There are two examples showing how adaptive management enhanced both the results of these trials and the understanding of what the results mean for the adoption of EEFs by farm advisors and farmers. The first is based on the social science component of the study completed by Casey Olechnowicz and Dr. Linda Prokopy at Purdue University. Eighteen agricultural consultants who participated in the project agreed to take part in pre- and post-project interviews. The interviews broadly explored certified crop advisors' (CCAs) attitudes toward nitrogen management, the EEF products used in the trials, motivations to participate in the trials, and anticipated benefits and challenges related to the trials.

In the interviews at the beginning of the project, many farmers and agricultural consultants were concerned about the logistics related to EEF use. However, in the post-project interviews, only a few consultants mentioned logistics related to EEF applications as a meaningful limitation to the use of the products. The main concern in the post-project interviews was the limitations of long-term forecasting of rainfall amounts and timing, which is critical to the profitability of EEFs.

We think the consultants and farmers changed their concerns about EEFs between the two interviews due to the learning that occurred through discussions about the data during our annual regional meetings and our final all-inclusive meeting at the annual Amplify Conference in San Antonio, Texas. There was much discussion at these meetings among participants and our project staff about the lack of a clear benefit to application of EEFs, which was confusing to everyone after the first year. However, with the addition of the second- and third-year's results combined with rainfall records from each trial location the discussions coalesced around the fact that insufficient rainfall during the critical 30 days after the application of the nitrification inhibitors or insufficient seasonal rainfall for BD-Ntrust was a primary driver of the uneven and disappointing performance of the EEFs. Without the interactive discussions about these facts and data, especially at the final meeting in San Antonio, we do not think the farmers and consultants would have responded on the post-project interview that long-term forecasting was a critical technology needed to create more reliable benefits from EEFs.

At the end of the project, all of the interviewed participants claimed a better understanding of EEFs, and they highlighted the strength in the collaborative nature of the trials connecting consulting groups, universities, agronomic advisors, and farmers. All the interviewees agreed that EEFs are a valuable management tool given the correct weather and soil conditions, and they wanted to continue to learn more about EEFs.

The full social science report is (available here).

The second example of adaptive management in action was the change in the comparisons of nitrogen rates in the design of the trials. Our project staff noticed that there was only a small difference in yields between the farmer's normal sidedress nitrogen rate and 75% of the farmer's normal sidedress rate. This prompted us to discuss this result with the consultants and farmers. After the discussion, we requested that farmers volunteer to apply a 50% of normal sidedress rate in the last year of the trials instead of the original 75% rate with the hope that the amount of insurance nitrogen would not interfere with the performance of the EEFs. Eleven farmers agreed to apply the 50% rate, which was considered risky by most farmers. Without the framework of adaptive management to use feedback to improve the project, the project team would not have thought to discuss this change to the design of the trials with the consultants and farmers.

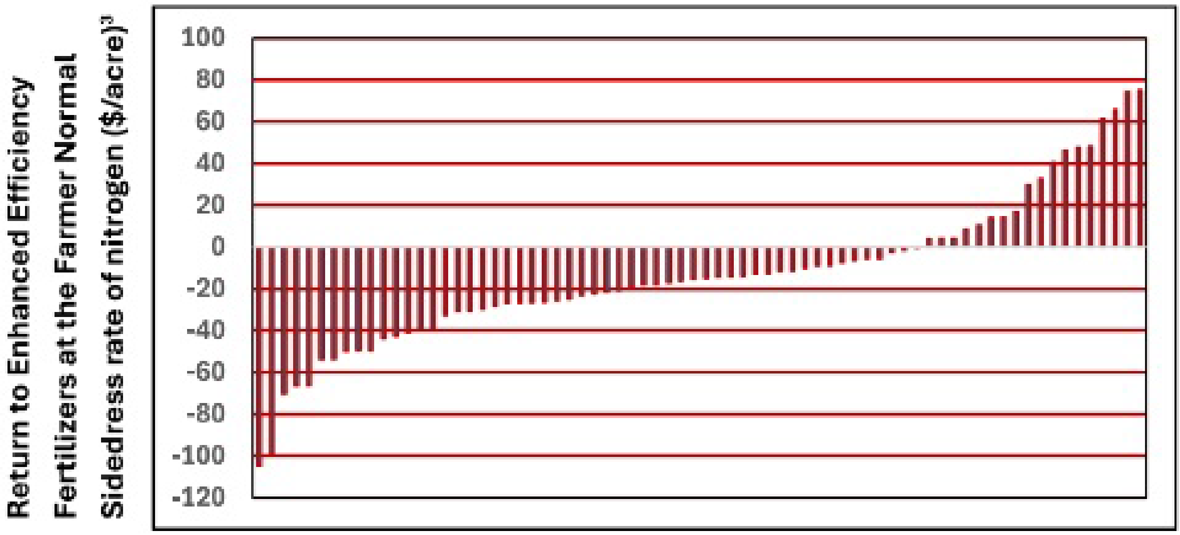
Objective 3.
Document the environmental and economic impacts of EEFs for farmers with a variety of soils, climates, farm operations, and practices.

We analyzed the results from the 72 trials that evaluated the three nitrification inhibitors, N-Serve, Instinct NXTGEN, and Centuro as a combined dataset to provide the most effective and convincing analysis. We also analyzed the results for the individual nitrification inhibitors and BD-Ntrust separately.

The first question we asked of the results was did the three nitrification inhibitors, N-Serve, Centuro, and Instinct NXTGEN, make money for the farmers when applied at the Farmer Normal rate of sidedress nitrogen? The answer was no. These EEFs did not pay for their additional costs compared with the cost of applying urea-ammonia nitrate (UAN) or anhydrous ammonia without an EEF. The average return to EEF applications was a negative $12.89 per acre at the Farmer Normal sidedress nitrogen rate. This value reflects the fact that yields for the Farmer Normal rate across the trials were similar, but the costs for the nitrification inhibitors added $13 to $20 per acre on average to the farmers' fertilizer costs. Returns to the

EEFs were positive at only 18 of the 72 trials, or 25% of the trials (Graph 1). Because farmers do not typically reduce their nitrogen rates when applying an EEF, these returns to EEF application reflect what many farmers likely would obtain if they applied the EEFs at the time of sidedressing.

Graph 1. Return to three enhanced efficiency fertilizers (N-Serve, Centuro and Instinct NXTGEN) when applied at the Farmer Normal rate of sidedress nitrogen at 72 trials from 2020 to 2022[1,2].



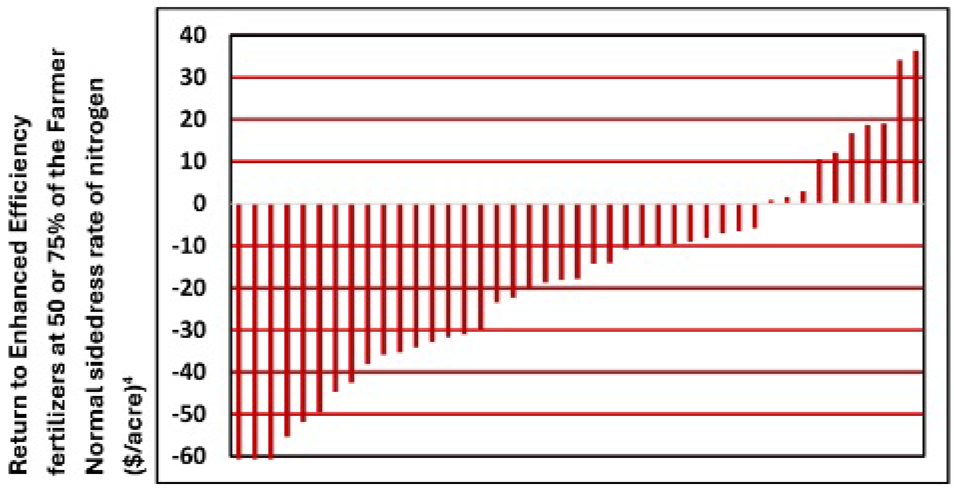
1 Each bar represents one trial.

2 The number of trials and types of enhanced efficiency fertilizers were: 11 trials N-Serve, 27 trials Instinct NXTGEN, and 33 trials Centuro.

3 Return to enhanced efficiency fertilizers= (Average yield for the Farmer Normal sidedress nitrogen rate with an EEF time the average cost per bushel of corn) minus (Average yield for the Farmer Normal yield times the average price of a bushel of corn) minus (average cost of the enhanced efficiency fertilizers). The costs of nitrogen and prices for corn used in the calculations varied among the years and were obtained by using the average prices and costs incurred by the farmers who carried out the trials. The costs and prices were: 2020: corn $5.50/bu, nitrogen $0.80 per pound; 2021: corn $5.50/bu, nitrogen $0.80 per pound; 2022: corn $6.50/bu, nitrogen $0.76 per pound. The costs for the enhanced efficiency fertilizers were: N-Serve $11.95/acre in 2020 and $16.39/acre in 2021 and 2022; Instinct NXTGEN $13.12/acre in 2020, $15.40 per acre in 2021, and $15.41/acre in 2022; Centuro $0.14/pound in 2020 and 2022, and $0.147/pound in 2021.

The second question we asked of the results was did the nitrification inhibitors make money for the farmers when applied at 50 or 75% of the Farmer Normal rate of sidedress nitrogen? The answer was no. These EEFs did not pay for their additional costs compared with the cost of applying UAN or anhydrous ammonia without an EEF. The average return to EEF applications was a negative $18.50 per acre when applied at 50 or 75% of the Farmer Normal sidedress nitrogen rate. This result was due to the additional cost of the EEFs and to differences in yields between the 50 or 75% of the Farmer Normal sidedress nitrogen rate with the EEF compared with the same rate of nitrogen without the EEF. Returns to the EEFs were positive at only 10 of the 43 trials, or 30% of the trials (Graph 2). These lower rates of nitrogen were applied to provide farmers with information about the performance of these EEFs at reduced rates of nitrogen.

Graph 2. Return to enhanced efficiency fertilizers (N-Serve, Centuro and Instinct NXTGEN) when applied at SO or 75 percent of the Farmer Normal rate of sidedress nitrogen at 43 trials in 2021 and 2022[1,2,3]_



1 Each bar represents one trial.

2 All seven of the trials at 50% of the Farmer Normal sidedress rate had negative returns to nitrogen.

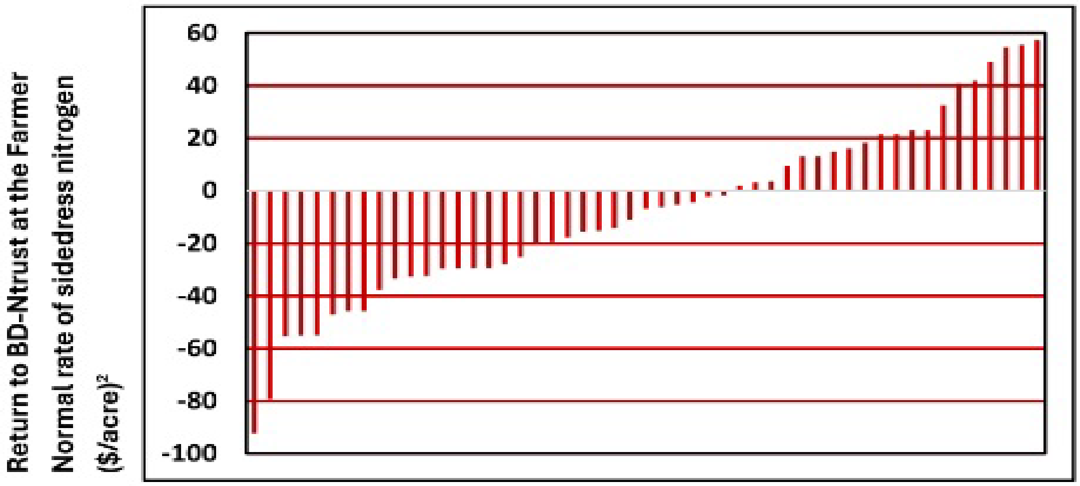
3 The number of trials and types of enhanced efficiency fertilizers were: 11 trials N-Serve, 27 trials Instinct NXTGEN, and 33 trials Centuro.

4 Return to enhanced efficiency fertilizers= (Average yield for the 50 or 75% of Farmer Normal sidedress nitrogen rate with an EEF times the average cost per bushel of corn) minus (Average yield for the SO or 75% Farmer Normal yield times the average price of a bushel of corn) minus (average cost of the enhanced efficiency fertilizers). The costs of nitrogen and prices for corn used in the calculations varied among years and were obtained by using the average prices and costs incurred by the farmers who carried out the trials. The costs and prices were: 2020: corn $5.50/bu, nitrogen $0.80 per pound; 2021: corn $5.50/bu, nitrogen $0.80 per pound; 2022: corn $6.50/bu, nitrogen $0.76 per pound. The costs for the enhanced efficiency fertilizers were: N-Serve $11.95/acre in 2020 and $16.39/acre in 2021 and 2022; Instinct NXTGEN $13.12/acre in 2020, $15.40 per acre in 2021, and $15.41/acre in 2022; Centuro $0.14/pound in 2020 and 2022, and $0.147/pound in 2021.

The results for BD-Ntrust were similar to the results for the three nitrification inhibitors reported above. BD-Ntrust is designed to work with applied liquid nitrogen fertilizers to maximize availability and utilization of nitrogen. BD-Ntrust contains diazotrophic microbes that fix nitrogen and ammonifying bacteria that enhance the nitrogen cycle. It also contains organic acids and chelated micronutrients (Biodyne, 2020).

BD-Ntrust did not pay for its additional cost compared with the cost of applying UAN without BD-Ntrust. The average return to BD-Ntrust applications was a negative $8.00 per acre when applied at the Farmer Normal sidedress nitrogen rate because the cost of BD-Ntrust was greater than the increase in yields from applying the product. Returns to BD-Ntrust were positive at only 20 of the 51 trials, or 39% of the trials (Graph 3). Because farmers do not typically reduce their nitrogen rates when applying an EEF like BD-Ntrust, these returns to BD-Ntrust application reflect what many farmers likely would obtain if they applied BD-Ntrust at the time of sidedressing.

Graph 3. Return to BD-Ntrust when applied at the Farmer Normal rate of sidedress nitrogen at 51 trials from 2020 to 2022[1].

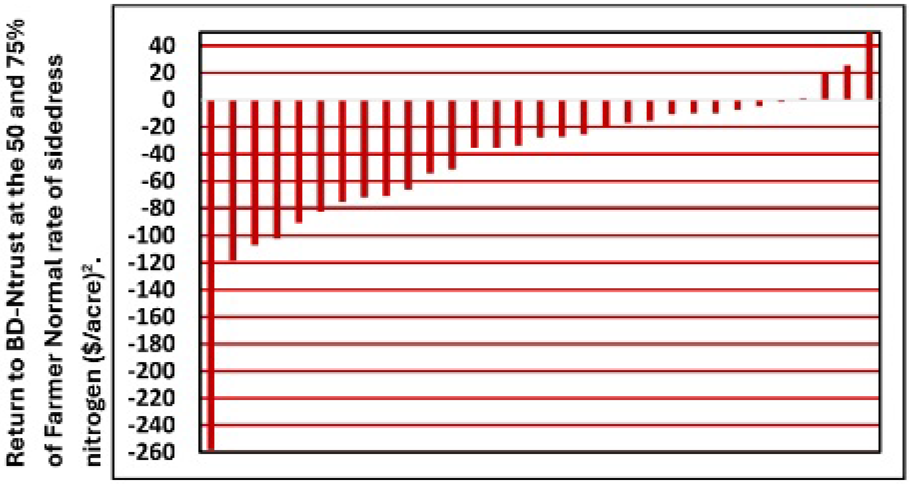


1 Each bar represents one trial.

2 Return to BD-Ntrust = (Average yield for the Farmer Normal sidedress nitrogen rate with BD-Ntrust times the average cost per bushel of corn) minus (Average yield for the Farmer Normal rate times the average price of a bushel of corn) minus (average cost of BD-Ntrust). The costs of nitrogen and prices for corn used in the calculations varied among years and were obtained by using the average prices and costs incurred by the farmers who carried out the trials. The costs and prices were: 2020: corn $5.50/bu, nitrogen $0.80 per pound; 2021: corn $5.50/bu, nitrogen $0.80 per pound; 2022: corn $6.50/bu, nitrogen $0.76 per pound. The costs for BD-Ntrust were $7.50/acre in 2020 and $12.75/acre in 2021 and 2022.

When BD-Ntrust was applied with UAN at 50 and 75% of the Farmer Normal rate of sidedress nitrogen the average return to BD-Ntrust was a negative $42.54 per acre. This result was due to the additional cost of the BD-Ntrust and to differences in yields between the 50 or 75% of the Farmer Normal sidedress nitrogen rate with BD-Ntrust compared with the same rate of nitrogen without BD-Ntrust. Returns to Bd-Ntrust were positive at only 4 of the 31 trials, or 13% of the trials (Graph 4). These lower rates of nitrogen were applied to provide farmers with information about the performance of BD-Ntrust when applied at reduced rates of nitrogen.

Graph 4. Return to BD-Ntrust when applied at 75 or 50 percent of the Farmer Normal rate of sidedress nitrogen at 43 trials in 2021 and 2022[1].



1 Each bar represents one trial.

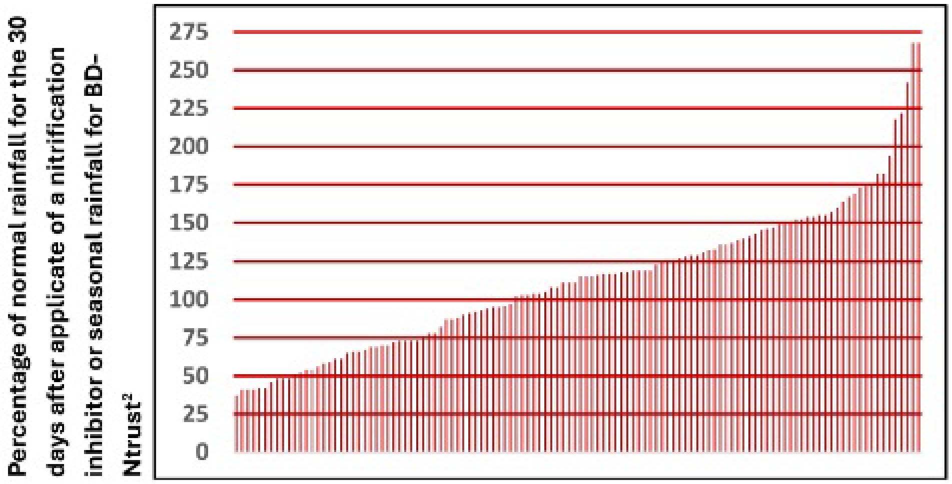
2 Return to BD-Ntrust = (Average yield for the SO or 7S% of Farmer Normal sidedress nitrogen rate with BD-Ntrust times the average cost per bushel of corn) minus (Average yield for the SO or 7S% of Farmer Normal rate times the average price of a bushel of corn) minus (average cost of BD-Ntrust). The costs of nitrogen and prices for corn used in the calculations varied among years and were obtained by using the average prices and costs incurred by the farmers who carried out the trials. The costs and prices were: 2020: corn $S.SO/bu, nitrogen $0.80 per pound; 2021: corn $S.SO/bu, nitrogen $0.80 per pound; 2022: corn $6.SO/bu, nitrogen $0.76 per pound. The costs for BD-Ntrust were $7.SO/acre in 2020 and $12.7S/acre in 2021 and 2022.

Our results showing negative returns on average to application of EEFs across these 123 trials were surprising. Because the trials were conducted across many different farmer practices, soils and environments across seven states there was no common factor except possibly rainfall to explain the results. Rainfall and large applications of insurance nitrogen fertilizer are the two main factors that could affect the performance of the EEFs.

Low rainfall relative to normal rainfall could result in only small losses of nitrogen and no need for an EEF, and large applications of insurance nitrogen also could result in no need for an EEF. Insurance nitrogen is an undefined amount of extra nitrogen fertilizer applied more than crop requirements (Mitsch et al., 2001; Argus, 2012). Farmers apply insurance nitrogen because after the application of nitrogen fertilizer, there is much uncertainty about how much of that fertilizer will be available to corn during the growing season.

We obtained rainfall amounts and timing at each trial from the NCEP Stage IV Daily Accumulations from the National Weather Service-Advanced Hydrologic Production Service. We were able to obtain accurate rainfall for 118 of the trials. The rainfall amounts were only 113% of normal on average for the periods when the nitrification inhibitors would provide the most protection to nitrogen, which is the 30 days after sidedress application, or when BD-Ntrust would provide enhanced nitrogen availability, which is from the date of application until August 31. Only 22 of the 118 trials (19%} received greater than 150% of normal rainfall (Graph 5}. A greater amount of rainfall must have been needed across these trials to make the EEFs profitable.

Graph 5. The percentage of normal rainfall for the 30 days after application of three nitrification inhibitors or the percentage of normal seasonal rainfall from the date of application of BD-Ntrust until August 31 across 118 trials from 2020 to 2022[1].



1 Each bar represents one trial.

2 Normal rainfall based on the 20-year period from 2003 to 2022.

It is difficult to know how much rainfall is needed to make an EEF a worthwhile investment because the amount of rainfall needed will be determined primarily by four factors:

1. The amount of insurance nitrogen included in a farmers normal nitrogen rate. The greater the insurance nitrogen the lower the chance of needing an EEF.
2. The type of soil in the field. Well-drained fields, especially sandy soils, will require less rain for leaching to occur compared with poorly drained fields. Poorly drained fields will require less rainfall for denitrification to occur compared with well-drained fields.
3. The amount of tile drainage in the field. More drainage increases the amount of rain required for denitrification and decreases the amount of rain required for leaching.
4. The moisture content of the soil when the rain occurs. Soils that are already wet will require less rainfall for leaching and denitrification compared with dry soils.

The inability to predict the amount of rainfall during the growing season and hence the amount of applied nitrogen that will be available to the corn crop is probably the primary reason EEFs were created. Farmers do not know early in the season, when they have to make decisions about their rate of nitrogen, whether the upcoming season will be wet with high losses of nitrogen, or dry, with low losses of nitrogen. This drives farmers to apply insurance rates of N that are higher than needed in below-normal and normal rainfall years, which occur more frequently than years with above-normal rainfall.

The way corn plants display visual symptoms of nitrogen sufficiency and deficiency also provides biased information to farmers about how much nitrogen fertilizer to apply. Corn plants show reliable and highly visible N deficiency symptoms; however, the plants show little to no visible symptoms of overfertilization with nitrogen. The easily observable deficiency symptoms with no feedback about overfertilization combined with greatly reduced yields from nitrogen deficiencies drive farmers to apply insurance nitrogen. The economics of nitrogen fertilization also drives applications of insurance nitrogen because nitrogen fertilization costs are small relative to the price of a bushel of corn. It typically requires only 5 bushels of corn to pay for 50 pounds of nitrogen fertilizer.

Both EEFs and the application of insurance nitrogen seek to insure against loss of yield from nitrogen deficiencies due to high rainfall during the growing season. However, applying large amounts of insurance nitrogen will greatly reduce the likelihood that the purchase of an EEF will be profitable because there already will be a large amount of extra nitrogen in the soil to guard against nitrogen deficiencies. Applying insurance nitrogen every year in amounts that guarantee sufficient nitrogen availability during seasons of high rainfall and paying for an EEF is the same as buying two insurance policies when only one is needed.

The number of trials completed in this project is the largest dataset evaluating EEFs on a field scale. But even this large dataset across three years only represents a small number of corn fields and environments across the Corn Belt. Because rainfall was the primary factor affecting the performance of the EEFs in our trials, we decided to examine the frequency of large rainfall events in three of the states where we had a large number of trials. We used the weather database at the Midwestern Regional Climate Center at Purdue University to obtain the average percentage of days in a month when one or two inches of rain fell in 24 hours from 2002 to 2021 during the growing season in Ohio, Illinois, and Indiana (Tables 1 and 2).

The probability of a one-inch rainfall in 24 hours was small ranging from a 2.7 percent chance to a 5.6 percent chance during the growing season. Two inches of rain in 24 hours occurred with less than a one percent chance for most of the states and most months. We cannot know how much rainfall is needed for an EEF to be profitable on any individual field because there are too many variables such as the amount of insurance nitrogen applied, soil texture, soil organic matter content, type of tillage, moisture content of the soil when a rainstorm occurs, extent of tile drainage and other factors that affect the loss of nitrogen from soils. The frequency of rainfall values in the tables below, however, provide a context for making decisions about applying an EEF.

Table 1. Average percent chance of a one inch or greater rainfall in 24 hours across Ohio, Indiana, and Illinois by various months[1,2].

State	April	May	June	July	August
	%	%	%	%	%
Ohio	2.7	2.8	3.7	3.7	2.9
Indiana	3.9	4.3	5.6	4.3	3.4

Illinois	3.4	3.6	4.6	4.4	3.2
Average	3.3	3.6	4.6	4.1	3.2

1 Average values for 20-year period from 2002 to 2021 obtained from the Midwestern Regional Climate Center database at Purdue University (https://mrcc.purdue.edu/).
2 Each state average is composed of values from eight rainfall stations within the state chosen to provide a good estimate of a statewide average.

Table 2. Average percent chance of a two inch or greater rainfall in 24 hours across Ohio, Indiana, and Illinois by various months[1,2].

State	April	May	June	July	August
	%	%	%	%	%
Ohio	0.1	0.3	0.5	0.5	0.6
Indiana	0.6	0.7	1.3	1.1	0.3
Illinois	0.7	0.7	1.1	0.8	0.8
Average	0.4	0.6	1.0	0.8	0.6

1 Average values for 20-year period from 2002 to 2021 obtained from the Midwestern Regional Climate Center database at Purdue University (https://mrcc.purdue.edu/).
2 Each state average is composed of values from eight rainfall stations within the state chosen to provide a good estimate of a statewide average.

Farmers may want to apply an EEF and NRCS may want to pay incentive payments to encourage application of EEFs for reasons other than profitability. Enhanced-efficiency fertilizers are known to reduce nitrous oxide (N2O) emissions from corn fields by up to 30% (Eagle et al., 2017). Nitrous oxide is a gas that is given off when nitrogen fertilizers are applied, and the gas is about 300 times more powerful as a greenhouse gas than carbon dioxide (CO2). The comprehensive review paper by Eagle et al. summarized the results from many experiments evaluating the effectiveness of EEFs to reduce nitrous oxide emissions from soils. The paper clearly showed that the application of EEFs, especially nitrification inhibitors, reduced nitrous oxide emissions on average by about 30%.

Objective 4.
Work with NRCS and other partners to develop and disseminate training, field days, and educational materials to facilitate the transfer of the On-Farm Evaluation Partnership model to other areas.
The results for this objective are reported in the Project Outputs below.

Project Outputs

Bulletins

We wrote five bulletins showing the results of the evaluation trials with interpretations explaining the reasons for the results. One bulletin was written for each of the EEFs evaluated, and a summary bulletin about the three nitrification inhibitors was written to provide more detailed interpretations of the results. The bulletins are available here.

Training and Outreach Events

Once restrictions for in-person meetings due to COVID were lifted, a member (or two) of the project gave presentations at CCA-type meetings in the Corn Belt. Members of the project staff spoke about the findings from the evaluations at a Field Data and Demo Day in Harlan, Iowa (30 attendees), the Illinois CCA meeting in Champaign, Illinois (150 attendees), the Great Lakes Crop Summit in Mount Pleasant, Michigan (70 attendees), the New England CCA Annual Meeting (45 attendees), and the Ohio Agribusiness Association Industry Conference in Columbus, Ohio (40 attendees).

The project staff also hosted Regional Summits to discuss the results with participants in the trials and guests invited by the participants. Those meetings were held in Bloomington, Illinois (20 attendees), Lansing, Michigan (30 attendees), and in New Bremen, Ohio (SO attendees). A final meeting to discuss all the results from the project was held at the Annual Amplify Conference in San Antonio, Texas (20 attendees).

The titles for these meetings varied, but all meetings and presentations revolved around the results of our field-scale evaluations of EEFs. There was a total of nine meetings and 455 attendees.

Computer Programs

When asking the farmers to reduce their nitrogen rates, it was noticed that the stabilizer rate needed to be adjusted for some products. To serve the participating farmers and make the application of the stabilizer easier and more accurate, the project staff created a stabilizer calculator (available here). The stabilizer calculator was designed to quickly calculate how much stabilizer was needed for the specified nitrogen rate. The stabilizer calculator tool was also mobile-phone-friendly so farmers and consultants could quickly and easily utilize the calculator tool.

Video for Training

To collect the highest quality of data, yield monitors need to be calibrated. Project staff member, John McGuire, hosted combine calibration clinics yearly for all farmers and consultants who were participating in the on-farm field trials. The Combine Calibration Demo was viewed by the people who would be operating the combine (often the farmer) to ensure they knew how to calibrate their combines to collect accurate, reliable, and repeatable yield data.

Field Trial Logistics Package

With any project, there are a lot of details to track. This CIG project was no different. A consultant packet was created to help consultants, farmers, and project staff know what to expect as the season progressed. Included in the consultant packet were a trial checklist, trial protocol, an EQIP eligibility form, a field history datasheet, stabilizer-specific plot layout sheets, stabilizer factsheets, and a blank W9 tax form. The entire consultant packet is (available here). All of the participating farmers and consultants appreciated the packet that was sent at the beginning of the season.

Sampling Guides for Collection of Cornstalk Nitrate Samples

We created four publications/tools to help participating farmers and consultants understand how to collect samples for the corn stalk nitrate test what data they are collecting and why it is important. Two stalk nitrate sampling publications were made. One publication is an illustration (available here) of how to take the samples and the other is written instructions (available here) on how to take the stalk nitrate samples. By having two different documents, we were able to accommodate more people's learning styles. Stalk nitrate sampling is time-sensitive and should be completed from the one-half-milk-line stage of growth until three weeks after the abscission (black) layer appears in corn. An illustration that was created to help teach farmers and consultants about the presence of the black layer is (available here)

Project Impacts

The 21 agricultural consultants in this project advise farmers who cultivate roughly 1.8 million acres of cropland, collectively. Based on the results of the pre- and post-interviews conducted by Casey Olechnowicz and Dr. Linda Prokopy at Purdue University the consultants understand the potential benefits and potential pitfalls to applying EEFs from participating in this project. As a result of participation in this project, the consultants can provide informed and accurate advice about two NRCS Conservation Practices: (1) improve plant health and productivity, and (2) reduce excess nutrients in surface and groundwater.

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