PROMOTING ADOPTION OF PRECISION NITROGEN MANAGEMENT TECHNOLOGIES THROUGH ON-FARM RESEARCH

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ABSTRACT

The Nebraska On-Farm Research Network helps farmers evaluate products and practices that impact the productivity, profitability, and sustainability of their operations. There are many technologies that have potential to increase nitrogen use efficiency (NUE) on corn and winter wheat but typically these technologies have low adoption. Concurrently, farmers have technologies such as GPS, yield monitors, and variable-rate application equipment on their farmers that enables them to easily conduct on-farm research to evaluate new technologies and products. Participating farmers evaluated commercially available nitrogen (N) management technologies across Nebraska and their impact on yield, profit, and NUE. We enabled farmer's hands-on experience with technologies that are relevant for their operation and promoted technology adoption. We also collected field data to validate and improve the technology tested. 40 trials are established each year in the three-year project. We utilized an innovative experimental design combining traditional strip trials with small N plots where all treatments are established with variable-rate fertilizer equipment on-the-go. An automated data processing tool was developed for data processing, analysis, and reporting. 98% of the experiments were successfully established in the first year of the study and 90% were analyzed using the automatic process. To measure impact, grower incremental changes in N management strategy and technology adoption were documented.

INTRODUCTION

Nitrogen (N) is critical for attaining higher crop yields; however, risks of environmental losses necessitate more precise fertilizer management. Predicting the economic optimum N rate (EONR) remains challenging due to spatial and temporal variability in crop yield, soil N supplying capacity, and N loss dynamics (Mamo et al., 2003). At the same time, there are an increasing number of technologies to improve N fertilizer efficiency by considering spatial and temporal variability (e.g., remote sensing and crop model-based tools), improving fertilizer efficiency (e.g., stabilizers, enhanced efficiency fertilizers, and inhibitors), or by relying on biological production of N (e.g., symbiotic N-fixing bacteria). These technologies provide paths for increasing NUE which is needed for more sustainable fertilizer management.

Despite the increase in available technologies, adoption of many of these technologies remains low (Lowenberg-Deboer and Erickson, 2019; Thompson et al., 2019a). On-farm research, where the farmer utilizes their equipment and land and plays a critical role in the research and discovery process, has been found to be a valuable means of technology transfer and important avenue to increasing adoption of technologies (Kyveryga, 2019; Thompson et al., 2019b; Lacoste et al., 2021). However, traditionally on-farm research has relied on field-length strips (often referred to as strip-trials) which while useful, have limited potential for testing spatial technologies and understanding site-specific, within-field technology performance (Kyveryga et al., 2018). Recently, the availability of precision ag technologies, including yield monitors and variable-rate application (VRA) equipment have made it possible to move beyond the traditional strip-trials used in on-farm research, greatly expanding the potential questions which can be addressed through on-farm research. Variable-rate application equipment is now being used to establish N rate blocks throughout farmer fields in whole-field “checkerboard” designs (Alesso et al., 2019; Bullock et al., 2019). Similarly, Scharf et al., 2005 established N rate blocks in contrasting field zones to determine the spatial variability of the EONR.

The Precision Nitrogen Project (PNP) was established to provide site-specific testing of N technologies and promote adoption by collaborating with farmers to inexpensively design and implement randomized agronomic field trials on whole commercial fields. From 2020 to 2022, the PNP project completed nearly 70 corn and wheat trials. In this work, we present a framework and procedures used by the multidisciplinary PNP team to implement on-farm precision experimentation (OFPE) to test N technologies. Specifically, we described (1) a farmer-centric, iterative, and tiered approach for N technology selection, (2) the use of a novel OFPE to benchmark and evaluate N technologies, (3) an automated OFPE data processing, management, analysis, and reporting system, and (4) the impact on cooperator management from three years of experimentation.

MATERIALS AND METHODS

Technology Selection

Cooperating farmers were engaged throughout the process by selecting the technology to test and by providing hands-on experience. Technologies were generally grouped as (1) crop model-based, (2) remote sensing-based, (3) enhanced efficiency fertilizers, and (4) biologicals (Figure 1). To guide this process, we utilized in-depth discussions with farmers, their crop advisors, extension educators, graduate students, and specialists to first understand the farmer’s current N management and technology capabilities and then to guide the selection of technology. This customized, farmer-centric approach increases the potential for future adoption of the technology tested and allows farmers to incrementally increase the complexity of their N management. For example, a farmer with no in-season N application capability might be given options of testing enhanced efficiency fertilizers or soil and management zone-based tools to direct VRA. However, a farmer with in-season N application capabilities might be given options for testing remote-sensing and crop model-based tools, which are tools recommended to be used during the growing season.

To provide growers with access to a variety of N technologies, we established public-private partnerships with industry. Partnerships with industry played a critical role in ensuring that technologies were implemented correctly. Cooperating farmers were provided with financial compensation to negate the cost and risk, reducing the barriers of testing a new technology.

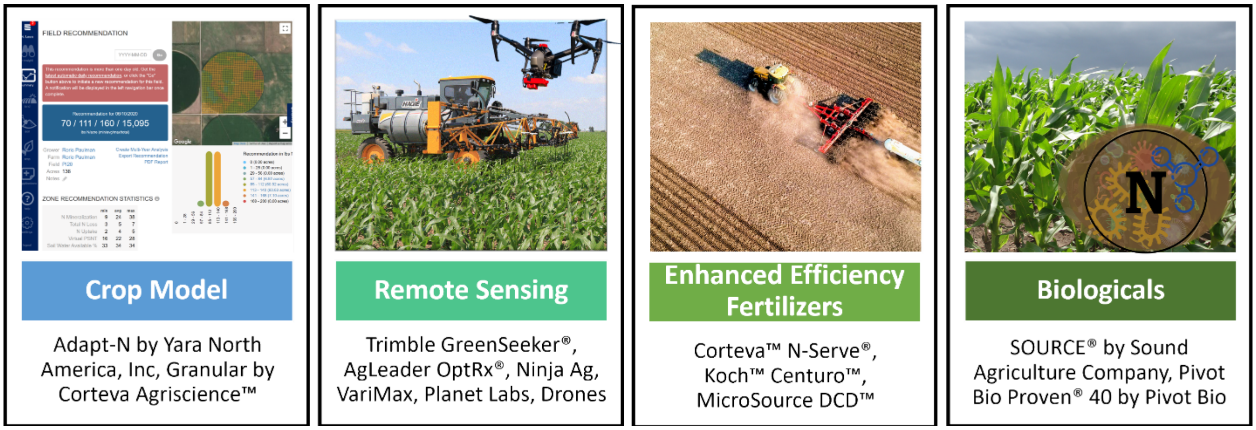

Figure 1. Nitrogen technology options for testing by cooperating farmers include crop model-based, remote sensing-based, enhanced efficiency fertilizers, and biologicals.

Novel On-Farm Precision Experimentation Design

Traditionally, on-farm research has used field-length strips to test differing products or practices. Recently, precision technologies such as yield monitors and VRA have enabled utilization of more diverse experimental designs in farmer fields, including placing smaller rate blocks throughout fields in a “checkerboard” design. In this work, we utilized a novel OFPE approach (Figure 2) which combines traditional strip-trials with small rate blocks allowing farmers to make a direct comparison of their approach to the new technology (through the strip-trials) while also benchmarking the technology performance (through small N blocks). The strip-trials were used to compare the farmers traditional management (“business-as-usual” N management) to the technology they are interested in (“next-level” N management). Nitrogen rate blocks are placed in contrasting zones of the field. For technologies that test different rates or timings (e.g., model-based and sensor-based N management) the technology was evaluated in field-length strips and N blocks were placed near the strip trials (Figure 2a). These rates for the strips and N blocks were assembled into a VRA that was implemented on-the-go using the farmer’s VRA controller. Nitrogen rate blocks for the biologicals and enhanced efficiency fertilizers strip-trials were implemented in a split-plot design (Figure 2b). Technologies were changed manually (in the case of enhanced efficiency fertilizers) or applied with a “split-planter” approach (in the case of biologicals). Nitrogen rate blocks were implemented as a prescription via the farmers VRA controller.

Data collection

Before the implementation of the field trial, we performed a soil characterization by measuring organic matter (OM) and soil texture stratified by depths at contrasting yielding areas of the field. During the growing season, we measured soil moisture and temperature, soil nitrate, crop phenology, plant biomass, high-resolution imagery, and leaf area index (LAI). Farmers provided as-applied and yield monitor data for the field-scale trials.

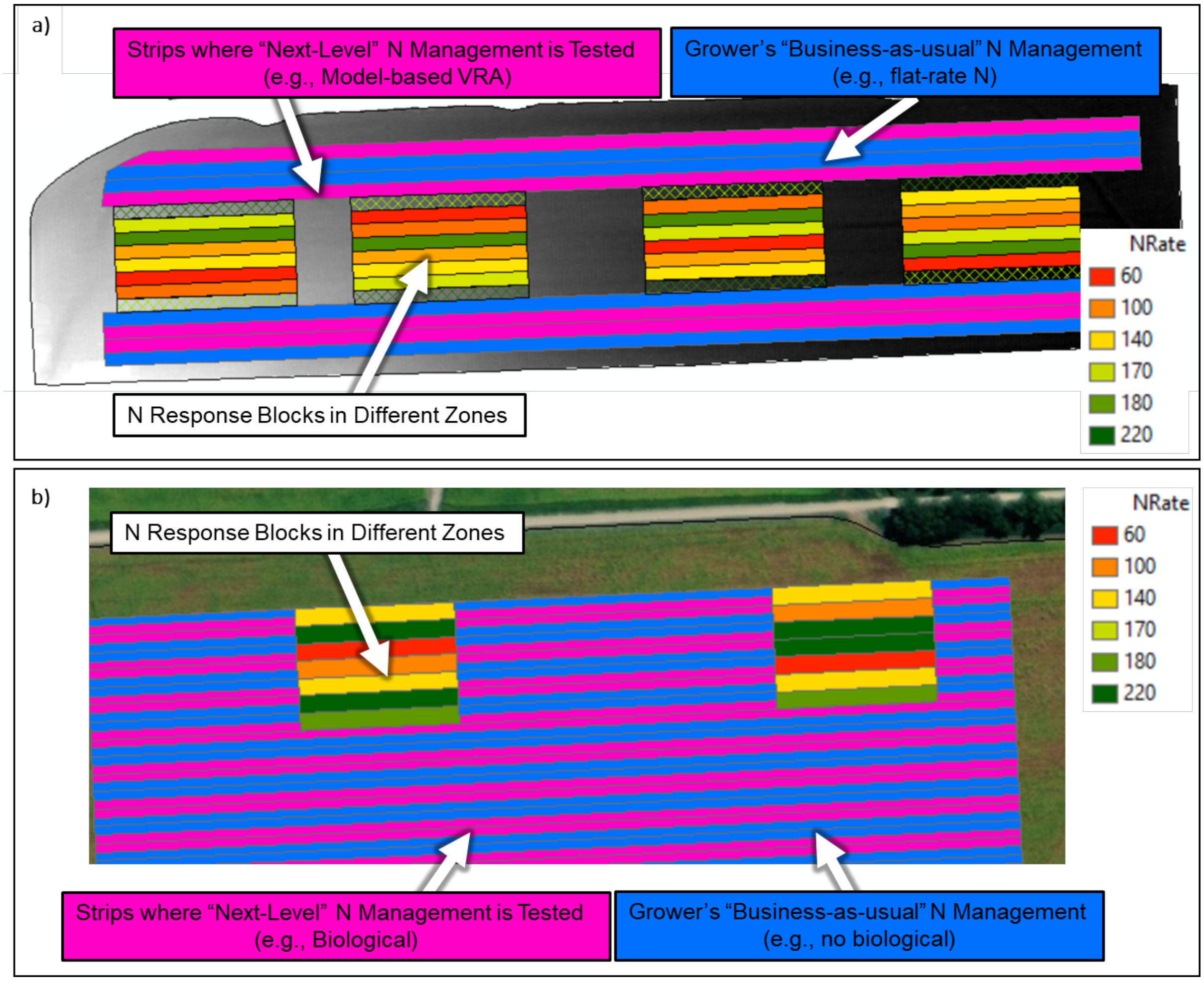

Figure 2. On-farm precision experimentation (OFPE) utilized to a) test technologies that adjust rate and/or timing (e.g., model-based and sensor-based) and benchmark the technologies using nitrogen (N) rate blocks and b) test technologies that use products (e.g., enhanced efficiency fertilizers and biologicals) and embed N rate blocks in a split-plot design to benchmark the technologies.

Automated Data Processing, Management, Analysis, and Reporting System

The farmer’s business-as-usual N management was compared to the next-level technology selected. We evaluated total N used, yield, profit, and NUE. Economic optimum N rate (EONR) was estimated for each N rate block to spatially benchmark the technology tested and the farmer traditional management. The development of an automated OFPE data processing, management, analysis, and reporting system was critical in enabling robust and quick data processing. This system aggregates data layers from various sources and implements data quality control methods to check for overlapping, misalignment, or outliers within yield and as-applied data. The system does not eliminate yield observation, instead, they get flagged when issues were found.

Currently, a Shiny App is under development to interactively share in-season and end of season results to growers. This is a final critical piece of the PNP to facilitate conversations between agronomists and farmers, share results, and ensure adoption of N technologies evaluated.

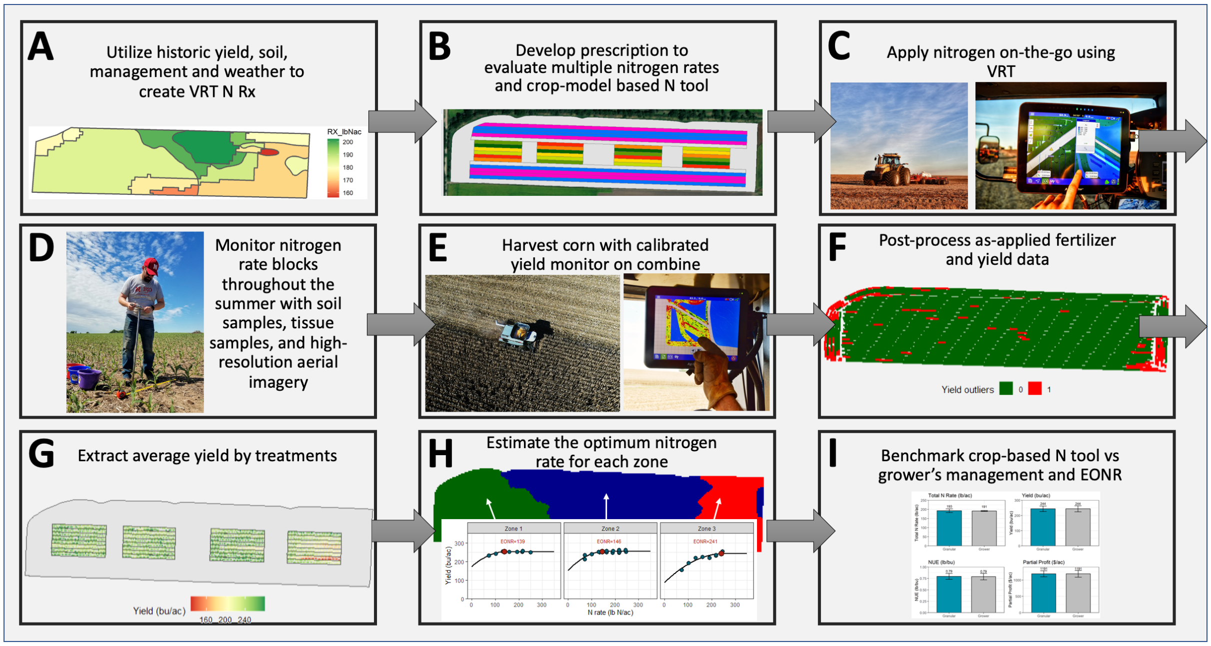

Figure 3. Precision nitrogen trial implementation workflow diagram: A) variable nitrogen rate prescriptions are created with the selected technology, B) trial layout is combined with the output of the technology and the nitrogen ramps , C) trials are applied on the go while the producers applies fertilizer, D) in-season data collection, E) end of season data collection, F) automatic data processing in R software, G) data summaries, H) analysis by zone, and I) data sharing.

RESULTS AND DISCUSSION

From 2020 to 2022, the PNP project completed nearly 70 trials in corn and wheat. Out of these trials, technologies selected were 39% crop model-based tools, 34% remote sensing-based, 21% enhanced efficiency fertilizers, and 6% biologicals. Biologicals were offered as an option for the first time in 2022 and we expect the interest in this N technology to increase in 2023. In 2021, 98% of the experiments were successfully established and 90% were analyzed using the automatic process and the reminder trials were analyzed manually due to issues in data quality. We expected to complete 120 trials by the end of year four of the PNP.

Due to this project, industry collaborations were established between academia and the growers. This facilitated technology transfer with expert input and allowed graduate students to be supported through industry collaborations. In addition, on-line workshop training sessions were organized to learn how to use some of these tools and allow growers to ask questions.

Results were shared with 200+ individuals annually through the on-farm research meetings and 12 presentations. Individual meetings were held to share results with the cooperating farmers. Farmer comments and stories revealed they were more comfortable using technology because of participating in this project. One producer noted, “I’ve had crop canopy sensors for years but didn’t feel confident using them. Now that I’ve seen the results, I will use them farm wide.” Growers also benefitted from seeing the results of the NUE analysis for their own management practices. One producer commented, “I’m shocked that our NUE is 1.1. I want to push the efficiency below 1. I was planning on purchasing some more fertilizer for the upcoming year, but now that I see these results, I think what I have is enough.”

Acknowledgements

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