THE IOWA NITROGEN INITATIVE

S. Archontoulis[1], M. Miller[1], M. Baum[1], R. Osman[1], and M. Castellano[1]
Iowa State University

ABSTRACT

The Iowa Nitrogen Initiative (INI) aims to enhance nitrogen fertilizer recommendations for corn and provide Iowans with the best nitrogen science for the benefit of productivity, profitability, and environmental performance. We are working alongside agricultural service providers, farmers, and their advisors to design, execute, and interpret hundreds of coordinated on-farm, scientifically robust, replicated nitrogen rate trials every year. Since 2022, INI started, more than 700 N-trials have been conducted across the state. Data collection protocols include grain yield, plant and soil nitrogen, and drone imagery. Data analyses include statistical and process-based (APSIM) modeling. On-farm trial results and simulation outputs will be displayed on a website that is currently under development. Results from this project will help understand the interactions among genetics, weather, soil type, and management on N-fertilization rate for corn and update information about decision making for optimum nitrogen management across Iowa.

INTRODUCTION

Optimum nitrogen (N) fertilizer rates for corn production are variable and changing over the years (Baum et al., 2024). Monitoring the spatial and temporal variability as well as the variability introduced in the optimum N rate by management practices (King et al., 2024) will provide stakeholders with valuable data to make informed decisions about how genetics and agronomic management – including, but not limited to N-fertilizer management – can be manipulated to maximize productivity, profitability and environmental performance. The Iowa Nitrogen Initiative (INI) launched in 2022 for this reason. In this proceeding, we describe the methods used by the INI (on-farm trials, data analytics) and provide initial results.

MATERIALS AND METHODS

On-farm nitrogen trials

Iowa Nitrogen Initiative (INI) trials are conducted in cooperation with private farmers and custom applicators on Iowa farm fields. Farmers work with precision agronomists contracted by Iowa State University (ISU) to create a custom nitrogen (N) application prescription that works in their existing fertilizer program. Each trial (5 to 10 acre area of the field) has five replicates of each of five treatments (N rates), resulting in 25 plots (each 0.25 to 0.33 acres). Replicates are randomized throughout the trial area. The size of the trial is determined by factors such as width of applicator, planting, and harvest equipment, the topography of the field, and direction traveled. One field may contain more than one trial; location is selected using historic yield maps to identify stable, high-yielding areas of the field and variable, low-yielding areas of the field for comparison.

Trials are conducted using a variety of N-sources, primarily NH3, urea, urea + AMS, UAN, and UAN + ATS. The N type and time of application is decided by the farmer. The N-rate treatments vary from trial-to-trial and are selected with respect to the farmer's operation and are at least 30 lbs N /acre apart. The source and method of N application may influence trial N-rates due to equipment or logistical limitations.

Following N application, the farmer or their custom applicator sends ISU the as-applied N data to determine successful trial application. Following harvest, ISU receives spatial yield files, and from these data, constructs a corn-nitrogen response curve. Additional management data such as planting date, hybrid, cover crops, tillage, drainage, and manure history are also collected. In all INI trials, drone flights are collected in August to visually inspect N-trial quality. In trials with a zero N-rate treatment, pre-planting, V6-stage and post harvesting soil samples are collected to determine soil inorganic N levels.

As of November 2024, the INI has performed 787 N-trials. A pilot study in 2022 included 67 trials. In 2023, approximately 270 N-trials were conducted across the state. In 2024, over 450 N-trials were placed. Over three years, 126 farmers across the state have conducted at least one N-trial.

Data analysis

The yield response to N-rate per trial is statistically analysed to determine the optimum N rate, the yield at the optimum N-rate, the yield at the zero N and the lbs N per bushel corn at the optimum N rate. Our approach to determine these parameters differs from the approach used in the MRTN tool (Nafziger et al., 2022). Instead of analyzing the N-trials one-by-one, we analyze the data all-together, creating a general use model similar to that of King et al. (2024) where we use the general model to determine parameters per N-trial. This approach offers several benefits. It allows us to fit regression curves in N-trial datasets with narrow N-rates, avoids the use of linear models that bias parameter estimates, eliminates bias introduced by fitting different types of regression models (e.g., linear plateau vs quantratic), and includes the factor year as a covariate so we can keep track temporal patterns in optimum N-rates (Baum et al., 2024a). The R software is used to perfom the above statistical analysis.

In addition, the INI team uses the Agricutlural Production Systems sIMulator (APSIM), a cropping systems biophysical model. This model can simulate a range of management options (tile drainage, cover crops, plant date, etc.) and provide productivity and environmental outcomes (crop yield, water stress, N2O emissions, N leaching, etc) based on nearly infinite combinations of genetics, environment, and managment. Inputs to the model include soil, weather, agronomic management and cultivar. The model has been improved over the years for Iowa cropping systems (Archontoulis et al., 2020) and is routinely used in research and extension (Baum et al., 2023; Archontoulis et al., 2021). We use the APSIM model to get insight into factors determined high/low yield and optimum N-rates in the on-farm N-trails, and to perform simulation experiments to increase the inference of the INI project. More specifically, we ran simulations per county, per weather year (1984–2024), and selected management options (N-rate,

planting date, residual soil N) to create a database to support benchmarking scenario analysis and educate stakeholders on N management.

Web-tool and information dissemination

Anonymized experimental data and model-based scenario data will be available through a public-facing web-based application currently in development. The information dissemination is built on major land resource area (MLRA), the USDA classification system for large areas of land with similar characteristics. This app is expected to launch Spring 2025.

RESULTS AND DISCUSSION

Analysis of the 2023 INI trials (n=270) indicated that the yield at the economic optimum N rate averaged 229 bu/acre with over 90% of the trials having an optimum yield greater than 200 bu/ac. The economic optimum N rate ranged from 100 to 337 lbs N/ac, with a mean of 190 lbs N/ac. The lbs of N per bushel of corn at the economic optimum N rate averaged 0.83 and ranged from 0.37 to 1.3 (Fig. 1). There values are comparable to Baum et al. (2024b) who reported lbs N per bushel by crop rotation and county in Iowa.

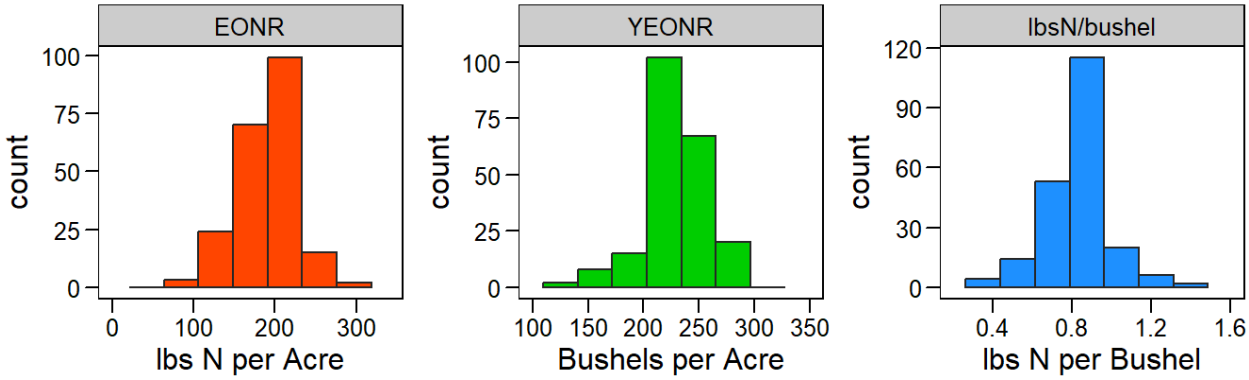

Fig. 1 Distribution of the economic optimum N rate (left), yield at the economic optimum N rate (middle) and lbs N per bushel (right) across all 2023 Iowa Nitrogen Initiative trials. On the y-axis, count refers to number of trials in each range data on the x-axis.

In 2023, we observed an east to west gradient in the economic optimum N rate (Fig. 2). This trend follows the historical precipitation patterns across the state. Within Northwest Iowa, and the Des Moines Lobe (top two MLRA's in terms of trial number) the mean economic optimum N rate was 182±50 and 203±28 lbs N per acre.

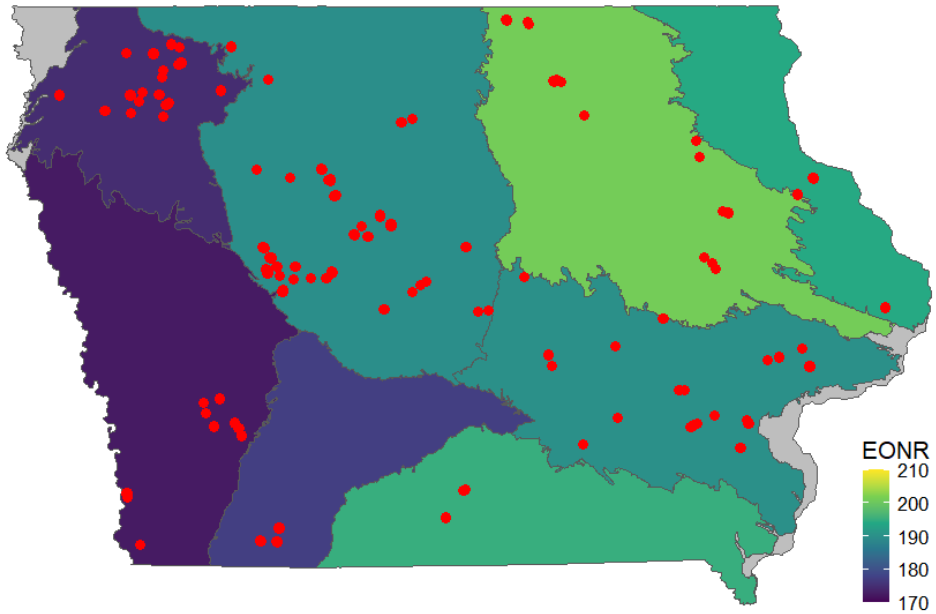

Fig. 2 Comparison of the mean economic optimum N rate per major land resource area (MLRA). Red points represent 2023 on-farm trials.

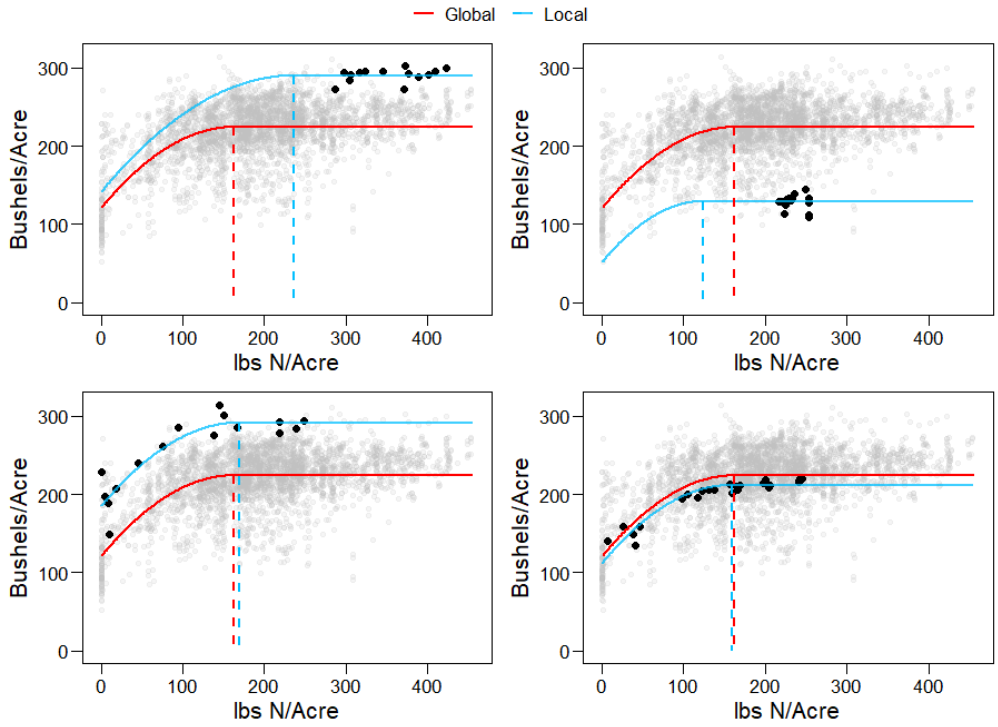

Fig 3 Yield response to N-fertilizer rate. Black points represent on-farm data for four different fields. Background grey points represent all the INI experimental datasets. Red line indicates the whole-dataset average statistical model (hereather global). The blue line indicates the on-farm specific fit of the global model (hereafter local). Vertical dotted lines indicate the economic optimum N rate.

A major innovation of the INI project is the way we analyze the data from the N-trials. Optimum N rate estimates per trial are derived using a mixed effect quadratic plateau model treating major land resource area, and crop rotation as fixed effects while each individual trial is treated as a random effect in the model. This approach allows for the global yield response curve to inform estimates from individual fields (Fig. 3). This is particularly useful in N-trials where the optimum N rate is outside of the applied N rate.

The APSIM model was capable of simulating the observed yield respose to N-rate (Fig. 4) and allowed us to get insight into the reasons for the observed responses. In addition to on-farm trials, we are testing the APSIM model capability in respresenting yield response to N rates by plant poppulation, corn relative maturity and other factors obtained in specialized INI experiments.

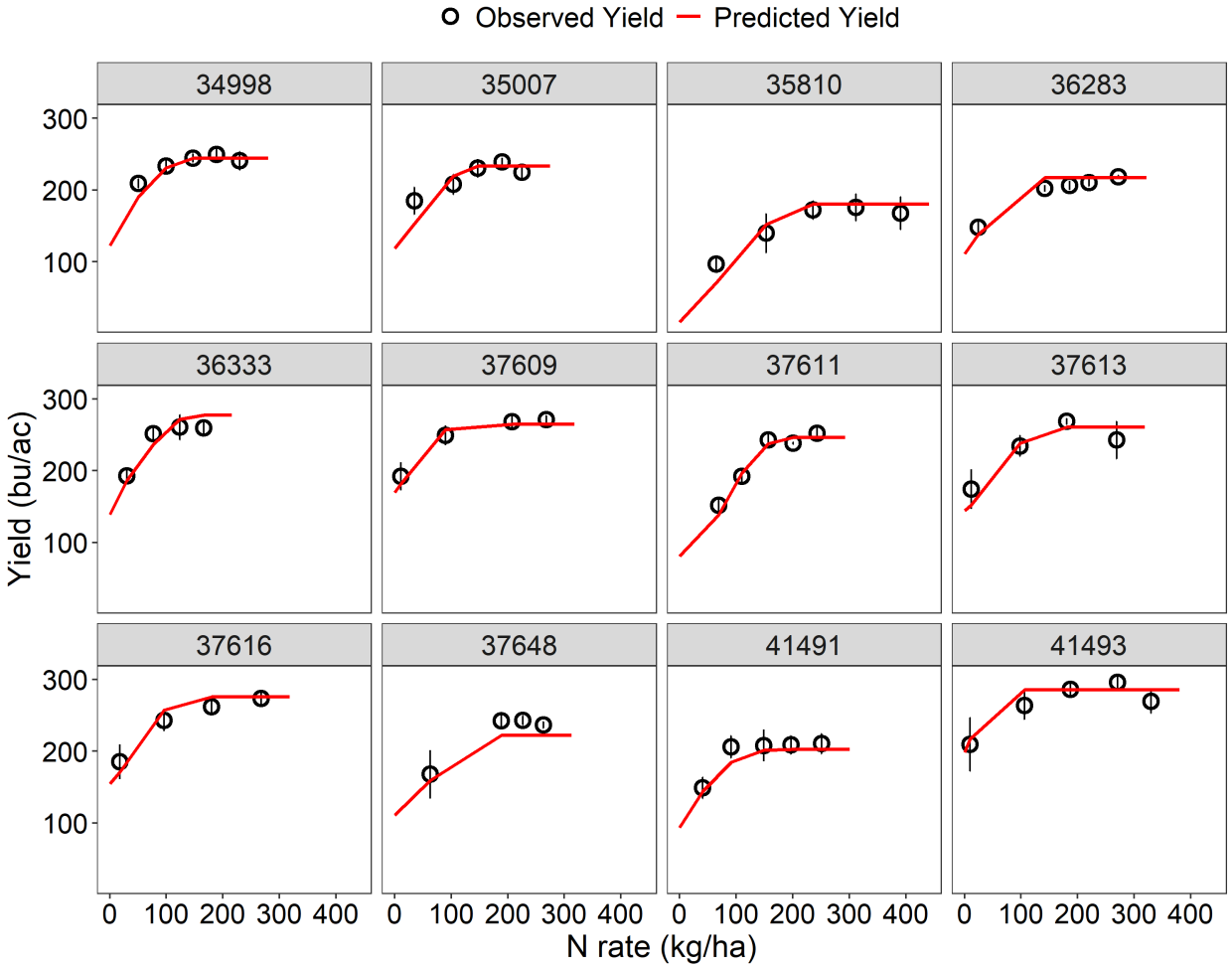

Fig. 4 Comparison of APSIM simulated (red line) and observed grain yield (open symbols) across various N fertilizer rates in a subset of the 2023 INI trials. Numerical acronyms refers to trial ID.

In summary, the INI has accumulated numerous N-trial datasets from farmers fields over the last 3 years (> 750 trials) and will continue to collect such data in the following

years. In addition, the INI has deployed new methods in data analysis and uses a biophysical model to expand the inference of the project by capturing more regions, weather variability, and management practices towards developing a bechamarking tool to improve state level N-rate recommendations and educate stakeholders on N-fertilizer management. This new approach will provide genotype by environment by management information that will allows farmers to improve further nitrogen use efficiency. Result dissemination, through a publicly-available web-tool, will begin Spring 2025. This work is possible through partnerships with the Iowa Department of Agriculture and Land Stewardship and Iowa farmers.

REFERENCES

Archontoulis SV, Castellano MJ, Licht MA, Nichols V, Baum M, Huber I, Martinez-Feria R, Puntel L, Ordónez RA, Iqbal J, Wright EE, Dietzel RN, Helmers M, Vanloocke A, Liebman M, Hatfield JL, Herzmann D, Cordova SC, Edmonds P, Togliatti K, Kessler A, Danalatos G, Pasley H, Pederson C, Lamkey KR, 2020. Predicting Crop Yields and Soil-Plant Nitrogen Dynamics in the US Corn Belt. Crop Science, 60: 721–738.

Archontoulis S, Licht M, Castellano M, 2021. FACTS soil moisture benchmarking tool. ICM blog news, Iowa State University

Baum M, Sawyer J, Nafziger E, Huber I, Thorburn P, Castellano M, Archontoulis, 2023. Evaluating and improving APSIM's capacity in simulating long-term corn yield response to nitrogen in continuous- and rotated-corn systems. Agricultural Systems 207, 103629

Baum M, Sawyer J, Nafziger E, Castellano M, McDaniel M, Licht M, Hayes D, Helmers M, Archontoulis S, 2024a. The optimum nitrogen fertilizer rate for maize in the US Midwest is increasing. Nature communications (accepted).

Baum M, Anderson D, Archontoulis S, Castellano M, 2024b. Pounds of nitrogen per bushel of corn – benchmarking farms against local averages. Iowa Extension publication, CROP 3181.

King K, Archontoulis SV, Baum M, Edwards JW, 2023. From a point to a range of optimum estimates for maize plant density and nitrogen recommendations. Agronomy J 116, 598-611.

Nafziger E, Sawyer J, Laboski C, Franzen D, 2022. The MRTN Approach to Making Nitrogen Rate Recommendations: Background and implementation. J. *Crops and Soils Magazine*.