PROGRESS REPORT

PROJECT TITLE: Dialing in the Most Corn-Profitable and Environmentally Responsible Nitrogen Rate
PROJECT NUMBER: Award CON000000096855; Project 00098087
REPORTING PERIOD: July-September 2023
PRINCIPAL INVESTIGATOR: Fabian G. Fernandez
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1.) PROJECT ACTIVITIES COMPLETED DURING THE REPORTING PERIOD. (*Describe project progress specific to goals, objectives, and deliverables identified in the project workplan.*)

The objectives of this study are to conduct a comprehensive study measuring the effect of various nitrogen rates on: 1) corn grain-yield, 2) economic return, 3) nitrogen use efficiency of corn, 4) nitrate leaching load in tile-drained fields, 5) nitrous oxide emissions, and 6) ammonia volatilization. An additional objective is to translate the information generated through this study into usable knowledge that can benefit Minnesota corn growers and society (including data for the MRTN calculator and generation of data to inform other models or tools that may become available).

During this quarter we conducted all the measurements specified in the funded protocol. At the end of this report, I include a list of field activities and a few pictures illustrating the activities conducted during this quarter to accomplish the goals and objectives of this project. Zac Aanerud, the Ph.D. student in the project has been a key contributor to the project and he is progressing very well in his degree. He will be taking his preliminary exams, a requirement for degree completion, this fall.

2.) IDENTIFY ANY SIGNIFICANT FINDINGS AND RESULTS OF THE PROJECT TO DATE.

At this point we have limited information or findings to share from this growing season, but we continue to update and use the information from this project to communicate the results to various audiences (see below). However, we have collected and process many samples and chemically analyzed some of the samples. We are in the process of organizing data and continue to process samples as quickly as we can. Because of the dry conditions, we are about two weeks ahead of schedule with crop development. The R6 samples were already collected on September 12, compared to September 29 last year. The recent large amounts of rain we saw in much of the state, which was so needed to reduce the drought conditions, did not happen in Lamberton. We only saw small amounts of rain there. Thus, grain harvest will be happening in early October. As in the past, this season we had wet and dry periods, the fact that we are taking a holistic approach to understand the different aspects of the N cycle (plant N uptake, soil N, nitrate leaching, and gaseous losses) is important to understand how different weather conditions through the growing season impact N availability and potential for loss.

3.) CHALLENGES ENCOUNTERED. (*Describe any challenges that you encountered related to project progress specific to goals, objectives, and deliverables identified in the project workplan.*)

No major challenges to report.

4.) FINANCIAL INFORMATION (*Describe any budget challenges and provide specific reasons for deviations from the projected project spending.*)

None to report

5.) EDUCATION AND OUTREACH ACTIVITES. *(Describe any conferences, workshops, field days, etc attended, number of contacts at each event, and/or publications developed to disseminate project results.)*

This is a minnegram article published in June about the project:
https://wrc.umn.edu/news/responsible-nitrogen
This is a video interview about the project: https://www.youtube.com/watch?v=QxlT__VO5lE
This is a recent CFANS article: https://cfans.umn.edu/news/aanerud-research-experience

This is an abstract submitted for the Water Resource Conference this upcoming October. We are also planning to attend the Tri-societies conference and the North Central Extension-Industry Soil Fertility Conference this fall.

Evaluating Nitrogen Loss Pathways and Corn Production in Southwestern Minnesota
Nitrogen (N) fertilizer is crucial for crop production, but it also contributes to environmental contamination. Nitrate in surface- and ground-water and ammonia and nitrous oxide in the atmosphere are primary contaminants from N fertilizers. This ongoing study started in 2021 at the University of Minnesota Southwest Research and Outreach Center in Lamberton, MN, to comprehensively assess the effects of varying N fertilizer rates (0 to 320 kg N ha^{-1} in 90 kg N ha^{-1} increments) on corn grain yield, profitability, and nitrogen loss (nitrate, nitrous oxide, and ammonia). The N rates were split applied with 90 kg N ha^{-1} as ESN pre-plant and the rest of the N was applied as Agrotain (urea + N-(n-Butyl)thiophosphoric triamide) at V6 development stage. The economic optimum N rate (EONR) was calculated at a fertilizer to corn price ratio of 0.0056 US\$1.10 kg^{-1} N (\$0.5 lb^{-1}) and \$196.84 Mg^{-1} of corn (\$5 $bushel^{-1}$). The EONR in 2021 was 130 kg N ha^{-1} (116 lbN $acre^{-1}$) and the grain yield at the EONR was 6.68 Mg ha^{-1} (106 bu $acre^{-1}$) and in 2022 the EONR was 177 kg N ha^{-1} (158 lb N $acre^{-1}$) and the grain yield at the EONR was 6.99 Mg ha^{-1} (111 bu $acre^{-1}$). The low yield and EONR reflected drought conditions in 2021 since there was minimal nitrate leaching (1.8 kg NO_3-N ha^{-1}), minimal nitrous oxide emissions (0.54 kg N_2O-N ha^{-1}) with the only significant emissions occurring after rainfall events, and ammonia volatilization was relatively low and similar between treatments. Compared to 2021, in 2022, early-season precipitation caused three times more N loss as nitrate leaching and two times more nitrous oxide emissions on average but slightly less ammonia volatilization and resulted in a higher EONR. However, dry conditions for the reminder of the growing season along with corn rootworm damage resulted in low grain yield. The 2023 season has contrasted with the previous two. Preliminary results highlight that weather conditions have a profound influence on successful N management.

July – September 2023 Activities:

Nitrous oxide gas sampling 3 times a week throughout the growing season.

V6 fertilizer application 6/12/2023
Ammonia Trap collection every 1, 4, 7, 14, 21, and 28 days after V6 fertilizer application.

V8 Rapid Scan
V10 whole plant samples 6/28/2023
V10 soil samples 6/27/2023

V10 Rapid Scan 6/27/2023
V12 Rapid Scan 7/7/2023
R6 whole plant samples and lower stalk samples 9/12/2023

Lab work extracting ammonia samples from acid traps. July – August

Evaluating Nitrogen Loss Pathways and Environmental Implications in Southwestern Minnesota Corn Fields

Soil, Water & Climate

UNIVERSITY OF MINNESOTA
Driven to Discover®

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Introduction

- Nitrogen (N) is an essential nutrient for crop production.
- The need for N as a fertilizer in food production and its presence as a contaminant in the environment creates a perplexing dilemma.
- Major pathways for N loss in agriculture include nitrate (NO_3) leaching, nitrous oxide (N_2O) denitrification, and ammonia (NH_3) volatilization.
- Limited number of studies evaluate in tandem agronomic and environmental outcomes of N management.

Objectives

1.) Determine environmental N losses [nitrate (NO_3), nitrous oxide (N_2O), and ammonia (NH_3)] and agronomic outcomes [corn (Zea mays L.) grain yield, profitability, plant and soil N removal, and N balance] in response to N rate.
2.) Determine the optimum N rate for profitable and environmentally responsible corn production.

Materials and Methods

Study Design

- Three-year study (2021-2023) in continuous corn at the Southwest Research and Outreach Center (SWROC) in Lamberton, MN.
- Webster clay loam (fineloamy, mixed, mesic Typic Haplaquoll)
- Plots drained individually with subsurface drains installed in 1994 at a depth of 1 m along with (12 mil) plastic film at a depth of 1.8 m in the perimeter of each plot to prevent lateral water flow.
- 15 plots [9.14 m wide (12 corn rows) x 18.29 m long]
- 5 N rate treatments (0 to 320 lbs N ac^{-1} in 80 lbs N ac^{-1} increments) and 3 replications in a randomized complete block design.
- ESN fertilizer was broadcast at 80 lbs N ac^{-1} and incorporated with tillage for all plots except the check before planting and Agrotain was applied at V6 to complete the N rate structure
- Annual precipitation for 2021 was 23.66 inches, 2022 was 20.13 inches the historic (1961-2022) average annual precipitation is 27.19 inches

Measurements

- Soil samples were collected pre-plant, at development stage V10, and post harvest at (0–30), (30 – 60), and (60 – 90) cm depth increments.
- NH_3 emissions were collected with acid traps at 1, 4, 7, 14, 21, and 28 days after each fertilization event.
- N_2O emissions were measured with MIRA Pico laser gas analyzer by Aeris Technologies two to three times per week during most of the growing season and less frequently late in the season
- Flow-proportionate water samples were collected when drainage occurred and analyzed for NO_3-N
- Plant samples were collected at V10, R6, and harvest and analyze for total N and stalk NO_3-N
- Weather data was collected from a nearby weather station

Figure 1. Field Site in Lamberton, MN

Funding

Water Resources Center
Minnesota Corn Growers Association
Nutrien
USGS science for a changing world

Results and Discussion

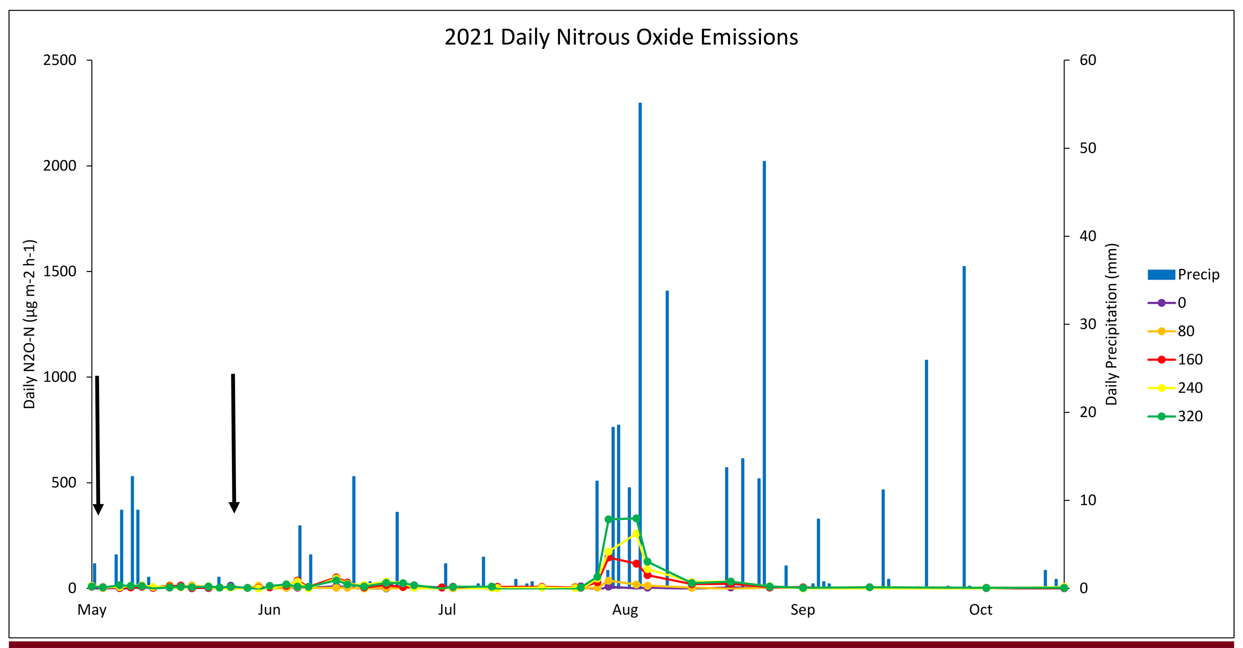

Figure 2. Daily N_2O-N emissions in response to treatment for 2021 and daily precipitation from 2021. Downward pointing arrows indicate pre-plant and split fertilizer application dates.

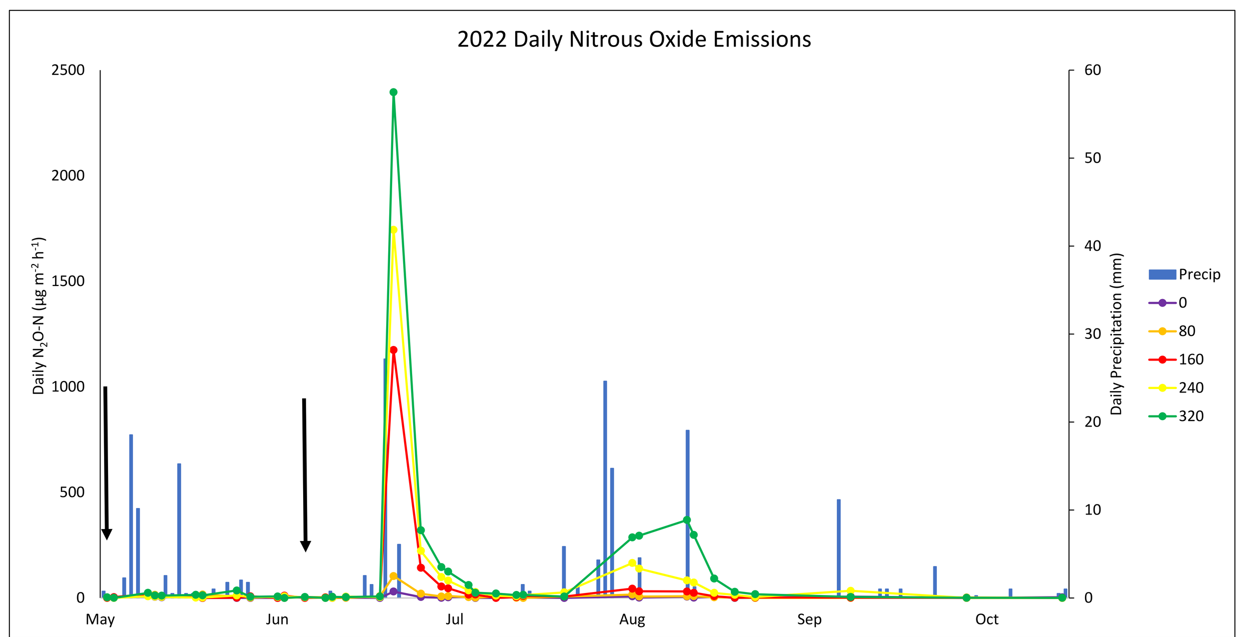

Figure 3. Daily N_2O-N emissions in response to treatment for 2022 and daily precipitation from 2022. Downward pointing arrows indicate pre-plant and split fertilizer application dates.

- N_2O fluxes were near background levels throughout the growing season and higher fluxes occurred only after precipitation for the higher N rates (Fig. 2 and 3).

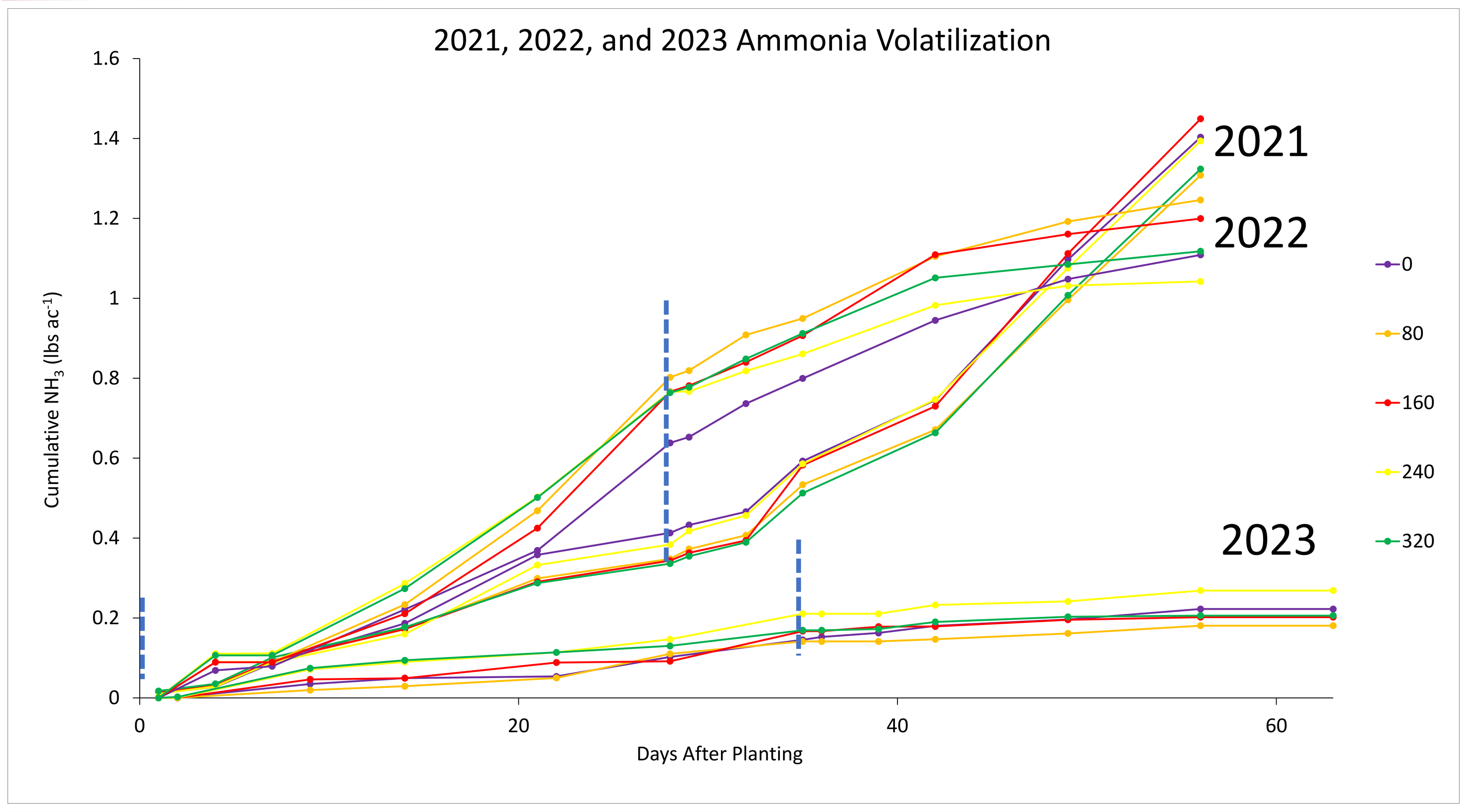

Figure 4.Cumulative NH_3-N volatilization loss as influenced by treatment over a 56-day period for 2021 and 2022 and a 63-day period for 2023 starting at pre-plant fertilizer application. Dotted blue lines indicate the split fertilizer application.

Figure 5. Switching out foams for ammonia collection using an acid trap method.

- Ammonia volatilization increased soon after fertilizer application regardless of timing or rate and drier conditions after the application increased volatilization (Fig. 4).
- 2021 had the highest cumulative ammonia volatilization and had the driest conditions after the application, whereas 2023 had the wettest conditions and had the lowest amount of ammonia volatilization (Fig. 4).

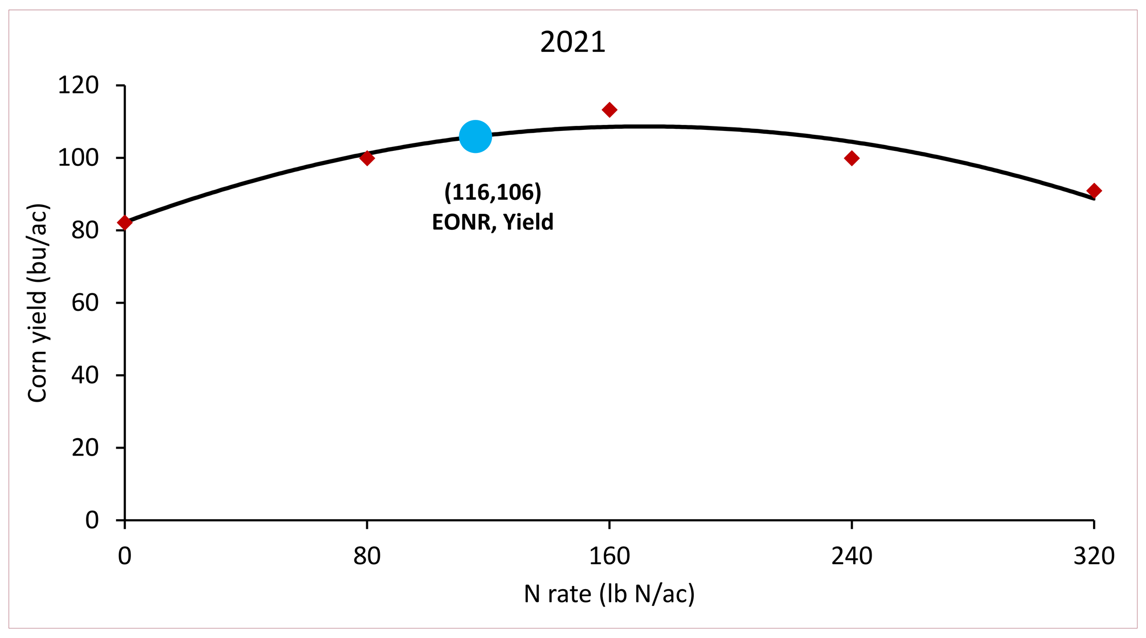

Figure 7. Agronomic trends in 2021 corn yields: quadratic regression analysis and EONR

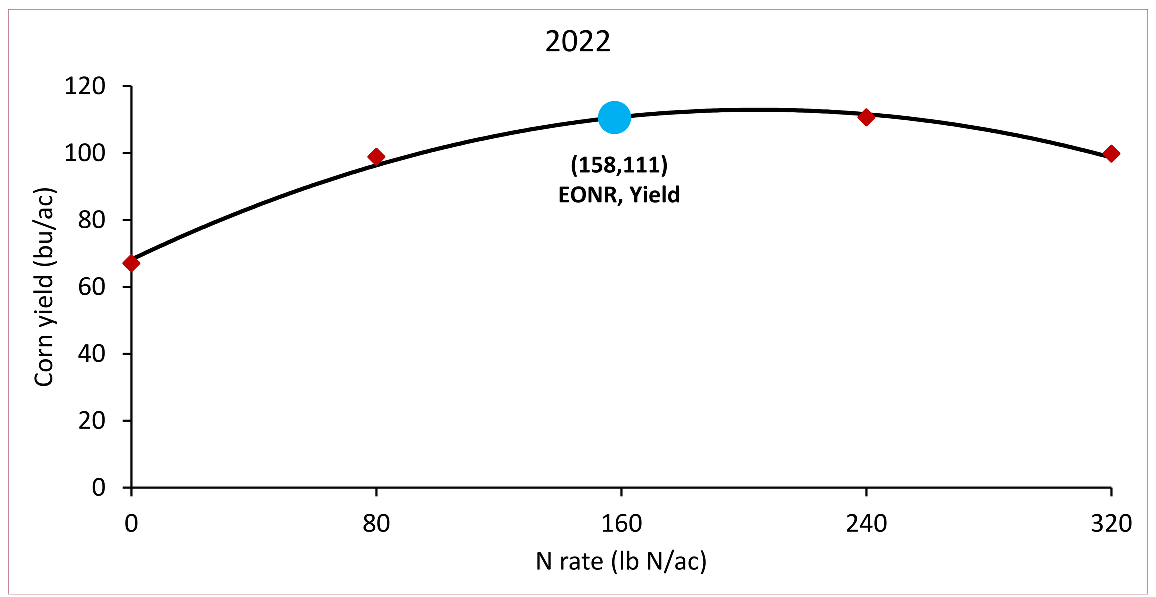

Figure 8. Agronomic trends in 2022 corn yields: quadratic regression analysis and EONR

- The economic optimum N rate (EONR) was calculated at a nitrogen to corn price ratio of 0.1 ($4 bu^{-1} of grain and $0.4 lbs^{-1} N fertilizer). For 2021 the EONR was very low, (116 lbs N ac^{-1}) and the grain yield at the EONR (and all N rates, Table 1 and 2) was also low (116 bu ac^{-1}) indicating that moisture was the limiting factor in 2021 (Fig. 7).
- In 2022 the EONR was (158 lbs N ac^{-1}) was greater than in 2021 likely resulting from N leaching losses that occurred early in the spring, but the grain yield at the EONR was still low (111 bu ac^{-1}) highlighting that dry conditions for most of the growing season (drier than 2021 overall) was again more limiting than N (Fig. 8).
- There was also corn root worm damage limiting yield.

Table 1. Summary table for 2021. NO_3-N load, flow weighted NO_3-N concentration, cumulative N_2O emissions, cumulative NH_3 emissions, and grain yield. Means with the same letter are snot significantly different from one another (P<0.10)

2021					
Treatment	Cumulative Nitrate-N Load	Average Flow Weighted Nitrate-N	Cumulative N_2O Emissions	Cumulative 56 day NH_3 Emissions	Grain Yield
lbs ac^{-1}	lbs ac^{-1}	mg L^{-1}	lbs ac^{-1}	lbs ac^{-1}	bu ac^{-1}
0	0.8A	5.2B	0.05A	1.40A	82B
80	1.5A	7.1AB	0.16A	1.31A	100AB
160	2.3A	7.0AB	0.52A	1.45A	113A
240	1.2A	8.5A	0.73A	1.39A	100AB
320	2.0A	7.9AB	0.96A	1.32A	91AB

Table 2. Summary table for 2022. NO_3-N load, flow weighted NO_3-N concentration, cumulative N_2O emissions, cumulative NH_3 emissions, and grain yield. Means with the same letter are snot significantly different from one another (P<0.10)

2022					
Treatment	Cumulative Nitrate-N Load	Average Flow Weighted Nitrate-N	Cumulative N_2O Emissions	Cumulative 56 day NH_3 Emissions	Grain Yield
lbs ac^{-1}	lbs ac^{-1}	mg L^{-1}	lbs ac^{-1}	lbs ac^{-1}	bu ac^{-1}
0	0.7B	2.8A	0.08C	1.11A	67B
80	3.1AB	3.9A	0.12C	1.25A	99AB
160	11.3A	9.8A	0.54BC	1.20A	110A
240	5.9AB	7.8A	2.06AB	1.04A	111A
320	6.3AB	11.6A	3.23A	1.12A	100AB

- More precipitation during the beginning of the 2022 field season resulted in more loss through nitrate leaching than in 2021 (Table 1 and 2).
- Nitrous oxide emissions increased with N rate (Table 1 and 2).
- Nitrous oxide emissions increased from 2021 to 2022 especially for treatments with split application (Table 1 and 2) because of precipitation close to the time of fertilization.
- Large nitrous oxide fluxes occurred in relation to rainfall events (Fig. 2 and 3).
- While there were no treatment differences, total ammonia volatilization decreased with greater precipitation soon after fertilization. It decreased from 2021 to 2022 and 2022 to 2023 (Fig.4 and Table 1 and 2).