CORN GRAIN YIELD RESPONSE TO NITROGEN RATE TIMING, SOURCE, AND NITRIFICATION INHIBITOR IN MISSOURI

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ABSTRACT

Nitrogen response depends on several factors including weather conditions, soil N supply capacity, previous crop in the rotation, plant population, and fertilizer management practices. Fertilizer management practices include fertilizer rate, source, application timing, placement, and use of nitrogen stabilizer. In Missouri, the nitrogen fertilizer rate recommendations for corn are based on a yield goal equation. This equation includes the target plant population, pounds of nitrogen removed per thousand plants, and a product of yield goal with pounds of nitrogen per yield unit. This equation has a soil health adjustment factor that is based on the organic matter content of the soil. The organic matter adjustment factor is based on soil texture and cation exchange capacity which provides a soil N credit in pounds of nitrogen per acre. The parameters used in the yield goal equation were updated in the 1980's. The yield goal equation does not integrate new practices such as cover crops, bio-stimulants, and nitrogen stabilizers. Moreover, the nitrogen recommendations do not incorporate variations in nitrogen supply across the landscape for different productivity zones. Therefore, a multi-site project funded by the Missouri Fertilizer Control Board began in 2023 to address these gaps, add new practices, and help update nitrogen fertilizer recommendations for Missouri. The specific objectives are to evaluate biological input products; cover crops; nitrification inhibitors and other biological management technologies for improving nitrogen use efficiencies; evaluate soil health indicators as yield predictors; evaluate the effect of landscape position and soil conditions on productivity and soil nitrogen supply; calibrate the integration of soil health measurements into fertilizer nitrogen recommendations and improve calibrations of in-season nitrogen prediction tools. Three-year results indicate that the factor for the internal N requirement of the corn plants was 1.06, which is 0.17 units more than the current factor. Nitrogen removal for 1000 corn plants was calculated to be 3.88 lb N ac^{-1} which indicates that the newer corn hybrids are more efficient in assimilating N in their biomass.

INTRODUCTION

The corn nitrogen (N) recommendation system for Missouri is a yield goal-based system. Most yield goal systems adopted in the US states are derived from Stanford's equation (Stanford, 1966). The derived yield goal equation is oversimplified where the N application rate (N_r) to corn is a factor of the internal N requirement of the corn plant (n) and expected yield from a field also called as yield goal (Morris et al., 2018). The n, internal N requirement of corn plants, is the maximum attainable yield developed from the rate response curves and varies from state to state (0.8 to 1.5 lbs N bu^{-1}). This approach overestimates the N recommendation in most cases and the oversimplification of this equation ignores several management practices which are known to affect the recovery efficiency of N by corn plants. The recovery efficiency (RE_N) is calculated based on the yield from the non-fertilized plot subtracted from the yield of the fertilized plot and divided by the N application rate (Cassman et al., 2002). It has been well documented that the RE_N varies with changes in management practices like fertilizer source, timing of application, placement of application, and use of enhanced efficiency products like nitrification or urea inhibitors in addition to the weather and temperature conditions (Hermelink, 2018).

In Missouri, the internal N requirement of corn plants is estimated based on the assumed plant population required for a given yield goal (Brown et al., 2004). For a corn stand of 1000 plants ac^{-1}, a total of 4 lb N ac^{-1} is added to the base recommendation which is 0.9 lb N ac^{-1} multiplied by the yield goal. Additionally, this equation is balanced by crediting N from soil texture and organic matter. The N credit system that was developed is a simplified table with three broad soil textural classes sand-sandy loam, silt loam-loam, and clay loam-clay. The soil N credit is further split into three organic matter classes within each soil textural class which varies from 20 lbs N ac^{-1} for sandy-sandy loam soil to 80 lbs N ac^{-1} for a silt loam to loam textural class. The approach of using an organic matter correction factor and adjustment to corn stand is unique to Missouri. The organic matter with a corresponding N credit which is probably related to the potentially mineralizable nitrogen are soil health indicators that are used in the N rate recommendation calculator for Missouri. The introduction of new technologies and new traits in corn hybrids with higher yield potential requires an updated N recommendation which should be tailored towards incorporating the complex dynamics of N functions in the soil geared towards improving RE_N and lowering environmental and economic loss of N fertilizer. To address this goal, the Missouri Fertilizer Control Board funded a multi-year multi-site project with specific objectives to evaluate biological input products; cover crops; nitrification inhibitors and other biological management technologies for improving N use efficiencies; evaluate soil health indicators as yield predictors; evaluate the effect of landscape position and soil conditions on productivity and soil N supply; calibrate the integration of soil health measurements into fertilizer N recommendations; and improve calibrations of in-season N prediction tools.

MATERIALS AND METHODS

This project involves soil and crop scientists working throughout the state located at Fisher Delta Research Center (FDRC), Bradford Research Center (BRC), Greenley Research Center (GRC), Forage Systems Research Center (FSRC), and USDA-ARS. The cropping systems in Missouri are different from Bootheelof Missouri to central Missouri and upstate Missouri. The seven counties in the Missouri Delta region also have cotton and rice as major crops. The cropping system is different from the rest of the state do to extensive flood irrigation. More than 90% of the cropland in central and upstate Missouri which includes 60 and 70% of the soybean and corn production in the state is under dryland production whereas it's more than 90% irrigated in the Bootheel. During

2023 and 2024, a total of 18 locations were established with the following projects evaluating N rate response in corn managed with different cultural practices.

Greenley Research Center (GRC):

1. Nitrogen timing (3) X Inhibitor (2) X N rate (5) - Corn. Evaluate N response with and without the inhibitor Centuro in fall with anhydrous, at preplant with anhydrous, and at V6 with UAN.
2. Landscape (3) X Inhibitor (3) X N rate (5) – Corn. Evaluate N response in three slope positions down a slope testing the inhibitors Centuro and N-serve at 120 and 180 lbs. N/acre.
3. Biological (3) X N rate (5) - Corn. Evaluate N response with three biologicals (Biological 1, Envita, and UtrishaN) with an untreated control.

In Upstate Missouri (GRC), corn response to N fertilizer rate, source, and timing was evaluated in the first study. The N rates selected for the study were 0, 60, 120, 180, and 240 lbs N ac^{-1}. Anhydrous ammonia with and without Centuro (nitrification inhibitor) was applied in the fall and as spring pre-plant. Additionally, UAN with and without Centuro at the same rates as anhydrous ammonia was applied at the V6 corn growth stage as a single application timing. In the second study, three landscape positions were classified using a topographic position model using LiDAR data in ArcGIS (Esri). Nitrogen rate responses of corn were evaluated for anhydrous ammonia applied as spring pre-plant at 0, 60, 120, 180, and 240 lbs N ac^{-1} rate. Additionally, 120 and 180 lbs N ac^{-1} with nitrification inhibitors (Centuro and N-serve) were also included as treatments. In the third-rate response trial, we evaluated three biological products applied at 0, 60, 120, 180, and 240 lbs N ac^{-1} N rates. Urea ammonium nitrate (32%) was used as an N-source applied at the V6 growth stage. Weather data were collected from the Missouri Mesonet at the GRC (Figure 1).

Bradford Research Center (BRC):

1. Landscape (2) X Cover Crop (2) X N rate (6) – Corn. Evaluate N response with and without cover crop at two landscape positions.
2. Cover crop (2) X N rate (6) – Corn. Evaluate N response with and without a cover crop.

In Central Missouri at the BRC, corn response to N was evaluated at two landscape positions with and without a winter rye cover crop with N applied at 0, 90, 120, 150, 180, and 210 lbs N ac^{-1} as UAN. The experiment was replicated at two locations. The second trial evaluated corn response to cover crops and no cover crops at two locations with N application rates of 0, 90, 120, 150, 180, and 210 lbs N ac^{-1} as UAN.

Fisher Delta Research Center: Biological (2) X N rate (7) – Corn. Evaluate N response with and without a biological.

At the Fisher Delta Research Center, N rates evaluated were 90, 120, 150, 180, 210, 240, and 270 lbs N ac^{-1} applied as UAN with or without a biological product applied as in-furrow liquid treatment. Throughout the year soil and tissue samples were collected as well as drone imagery. At the end of the season, the center two rows of each plot were harvested to calculate grain yield from grain weight and harvest moisture.

Statistical analysis:

The statistical analysis was performed using R-studio, SAS, and graphs were developed in Sigmplot or Origin Pro software.

RESULTS AND DISCUSSION

The 22-year average precipitation at the GRC location was 38.9 inches (Figure 1). Precipitation received in 2022, 2023, and 2024 was 30.5, 24.5, and 29.3 inches, respectively. The agronomically optimum nitrogen rates (AONR) and economically optimum nitrogen rates (EONR) were calculated for all data irrespective of the nitrogen sources, placement, timing, and use of nitrogen stabilizers (Figure 2). The AONR for 16 site-years of data was 212 lbs N/ac whereas EONR was 168 lbs N/ac. Nitrogen rate response curves were split based on the year. In 2022, the observed AONR was 196 lbs N/ac and EONR was 178 lbs N/ac. During a drought year (2023), lower overall corn grain yields were observed due to lower moisture availability during the growing season (Figure 2). The AONR in 2023 was 109 lbs N/ac and EONR was 152 lbs N/ac. In 2024, rainfall during the growing season was well-distributed which resulted in the highest corn grain yield among all years of the study. The AONR for 2024 was 235 lbs N/ac whereas EONR was 177 lbs N/ac.

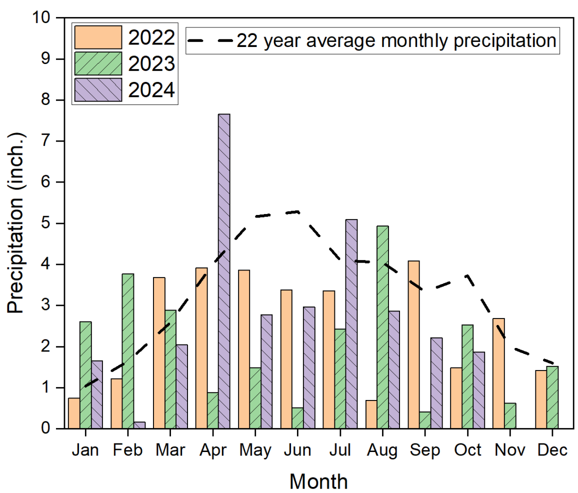

Figure 1. Precipitation received during 2022, 2023, and 2024 at the Novelty location in Northeast Missouri. The dashed line is the 22-years historic monthly precipitation.

At the Central Missouri location, reductions in corn grain yields were observed in the presence of cover crops (a difference of 11 bushels/acre; Figure 4. Although yield differences appeared, there were fewer differences among in-season corn plant measurements (e.g., color and biomass; Figure 4). The decrease in yield was likely due to early and mid-season water stress when the number of kernels per row was set (data still pending review). Treatments that had cover crops likely had less soil water and exhibited additional water stress (soil moisture measurements were not recorded). While treatment differences were observed, nitrogen response was similar (Figure 4). The 2023 drought conditions led to more water stress than nitrogen stress which minimized any large difference that we were expecting to observe from these studies.

Evaluating soil health parameters' and the correlation with yield at different nitrogen fertility levels revealed weak relationships for certain variables (Figure 5). The yield results with no additional nitrogenshowed pH, neutralizable acidity, and water aggregate stability were significant, but they were weakly correlated. More variables were correlated with yield from plots that received an excessive amount of nitrogen. These included pH, neutralizable acidity, active carbon (POXC), potential mineralizable nitrogen, and soil respiration. However, not all indicators were positively correlated (i.e., the more of the test value the higher the yield). This is a promising initial finding that needs to be revisited with data from non-drought years.

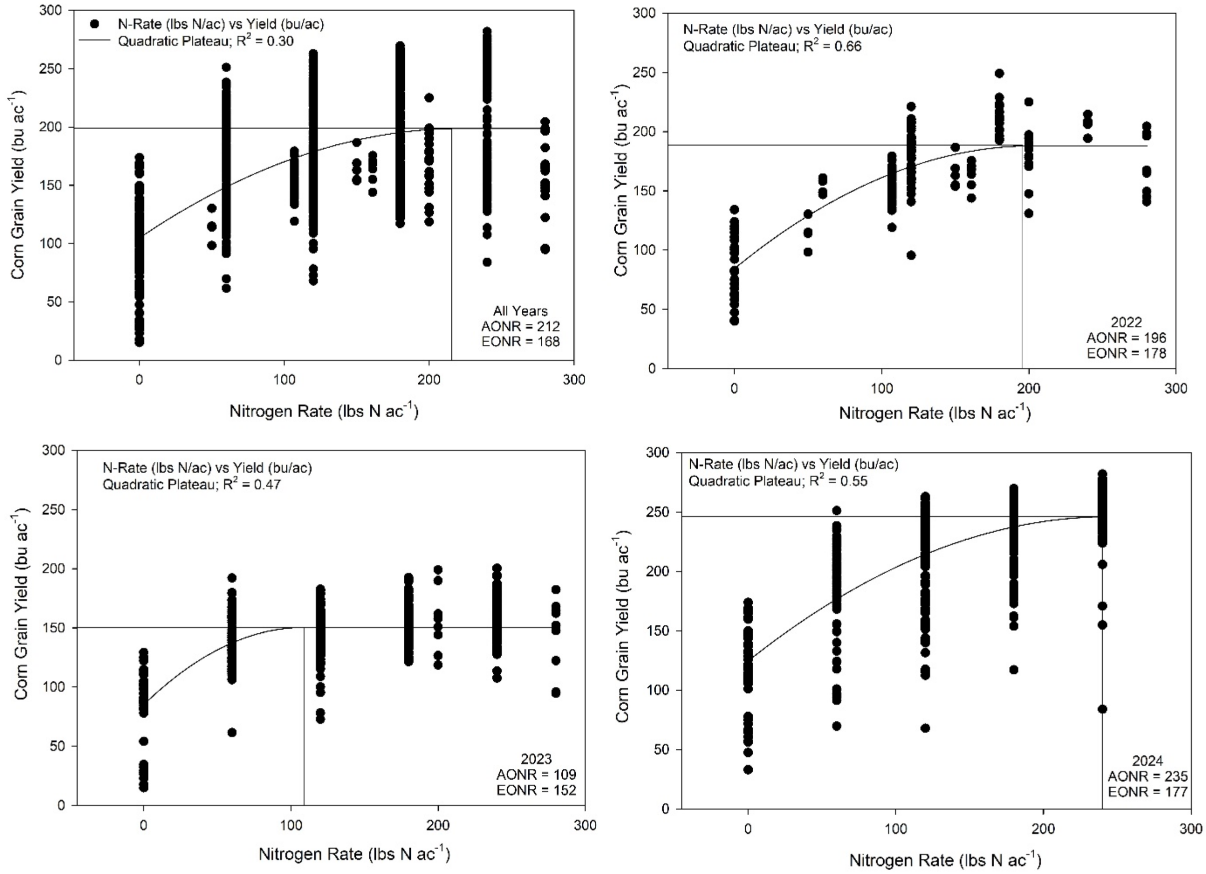

Figure 2. Nitrogen rate response curves from 16 site-years of data produced in Northeast Missouri at the Greenley Research Center.

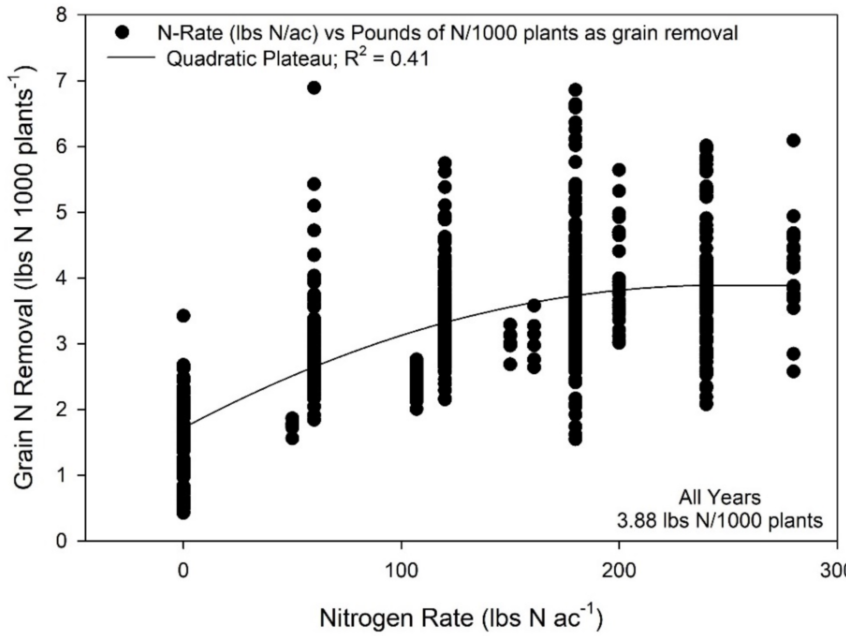

Figure 3. Grain nitrogen removal for 1000 corn plants at 16 site-years of data in Northeast Missouri Greenley Research Center.

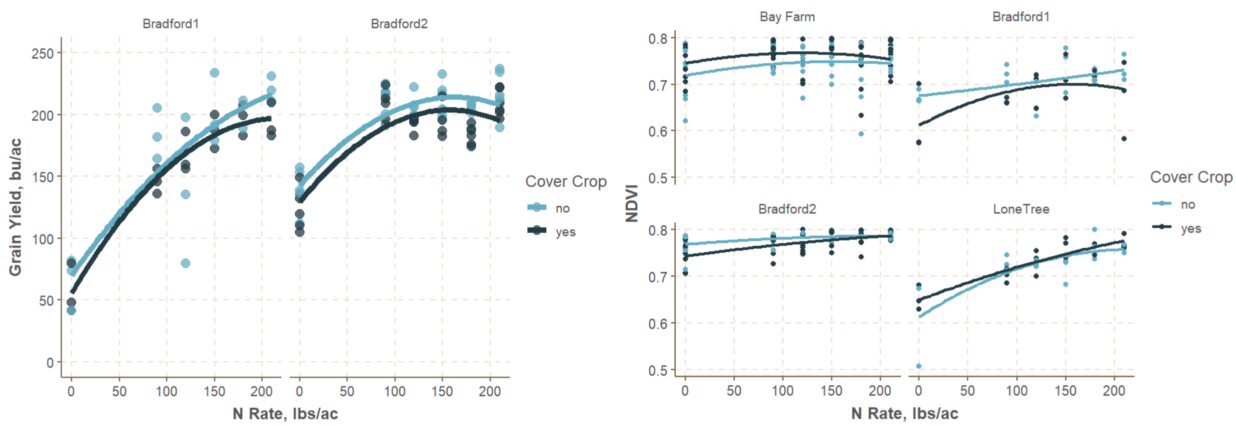

Figure 4. Corn grain yield response to nitrogen fertilization with and without a cereal rye cover crop in 2023. Corn plant greenness and biomass using normalized difference vegetative index (NDVI) for treatments with and without a cover crop in 2023.

Figure 5. Initial correlation coefficients of soil health (physical, chemical, and biological) indicators at two N rates. The closer the values are to 1 or -1 indicates a strong correlation to yield. Yields at two different fertility levels (0 lbs N/acre and 210 lbs N/acre applied) are shown.

At the Fisher Delta location, results indicated that biological products had no significant effect on N response in 2023 (Figure 6.). Only N rates significantly impacted corn yield. Generally, as the N rate increased, corn yield also increased under the irrigated growing conditions.

CONCLUSION

The factor for the internal N requirement of the corn plants based on the three years and 16 site-years of data was 1.06, which is 0.17 units more than the current factor. Nitrogen removal for 1000 corn plants was calculated to be 3.88 lb N ac^{-1} which indicates that newer corn hybrids are more efficient in assimilating N in their biomass. The preliminary analysis of soil health indicators showed some weak correlations with corn grain yield. For Missouri's corn N calculation equation, a credit is given based on the organic matter in the soil which varies from 20 lbs N ac^{-1} for sandy-sandy loam soil to 80 lbs N ac^{-1} for silt loam to loam. Data from soil health indicators will be further explored for their role in providing N credits and may help modify the existing corn N calculator equation.

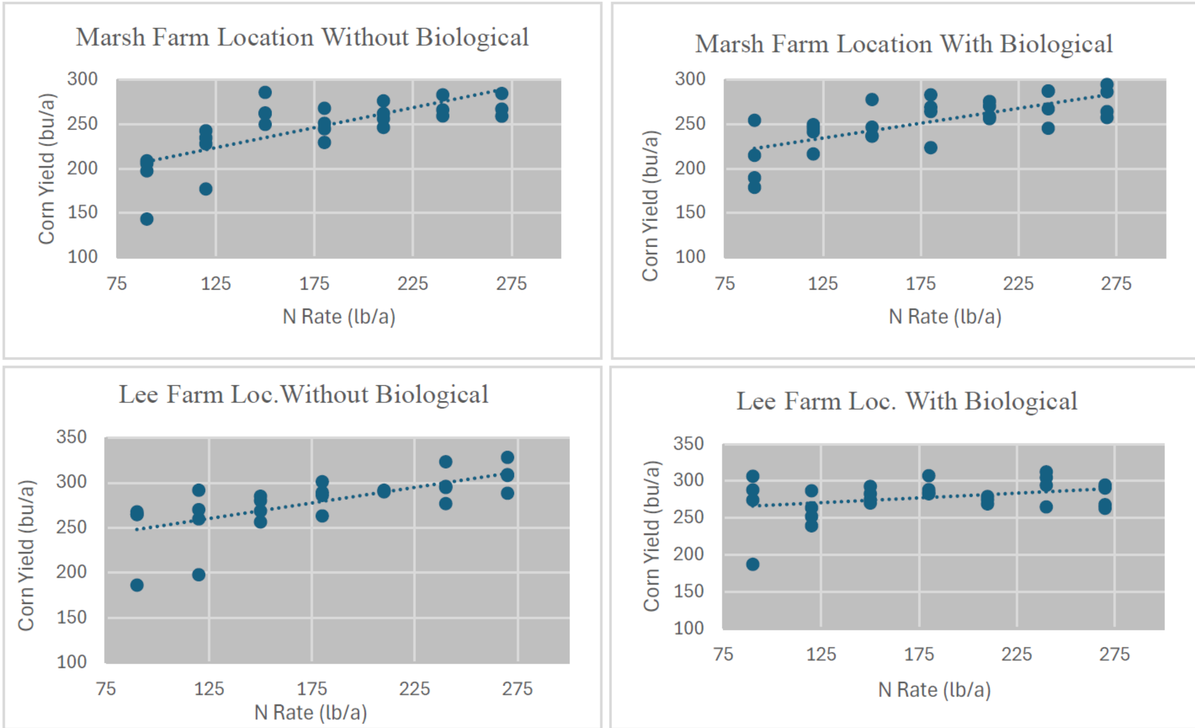

Figure 6. Corn grain yield response to nitrogen rates applied with and without a biological product at the Lee and Marsh farms in 2023.

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