OPTIMIZING NITROGEN MANAGEMENT FOR SUSTAINABLE PRODUCTION OF FURROW-IRRIGATED CORN IN NEBRASKA PANHANDLE

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ABSTRACT

Losses of nitrogen (N) via leaching to groundwater and greenhouse gas emissions pose an environmental and human health threat. The risk for environmental N losses, particularly nitrate leaching loss, is greater in furrow-irrigated fields than those under drip or sprinkler irrigation. Furrow irrigation accounts for 30% of total irrigated acres in Nebraska and approximately 36% in the US. However, much of the efforts for N management improvement are concentrated on sprinkler or drip systems. The two-year experiment was conducted to evaluate the effects of urea, polymer-coated urea (PCU), and urea with urease and nitrification inhibitors (UI) on grain yield, nitrate leaching, and nitrous oxide emission in furrow-irrigated corn at the UNL Panhandle Research, Extension, and Education Center in Scottsbluff, NE. The main treatment included three N sources at four N rates (50%, 75%, 100%, and 125% of recommended rate). Corn grain yield differed by applied N rates in 2021 but not in 2022, when yield was overall low due to drought and irrigation issues. When averaged across N rates, grain yield was in the order SuperU>PCU=urea>control in 2021. In 2022, nitrate concentrations in potential drainage water were lower than in 2021. Given full irrigation, N management in furrow-irrigated corn can be optimized with the use of UI.

INTRODUCTION

Optimization of fertilizer N application is critical to simultaneously ensure increased grain yield and reduced environmental risk. Irrigated fields are prone to nitrate leaching, with a greater risk in furrow-irrigated croplands than fields under drip or sprinkler irrigation (Siyal and Siyal, 2013). Although there has been a substantial shift in irrigation systems from gravity/furrow to potentially more efficient sprinkler and drip irrigation systems, the gravity flow method accounted for approximately 36 % of irrigation systems in the U.S. in 2018 (USDA-NASS, 2018). In Nebraska, furrow irrigation accounts for around 30% of total irrigation, and almost 38% of the area with furrow irrigation systems falls under areas of high nitrate concentrations (≥10 mg NO_3-N/L) (Juntakut, 2018).

Optimal rates and the right source of fertilizer N can help reduce nitrate leaching. The use of available advanced fertilizer technologies has been reported to reduce nitrate leaching from irrigated corn fields in several instances (Rui et al., 2019; Peng et al., 2015; Motavalli et al., 2008; Ferguson, 2015; Delgado & Bausch, 2005; Li et al., 2016) and this may potentially benefit furrow irrigation system as well. These products are designed to release N more gradually over the course of the season compared with conventional fertilizers to minimize N losses and improve synchrony between soil N availability and crop N demand. Several field experiments have reported the use of such products to optimize N management in corn (Hatfield & Parkin, 2014; DeBruin et al., 2020), but most of them are solely focused on agronomic output and under sprinkler irrigation. Halvorson and Bartolo (2014) reported the potential benefits of such advanced fertilizer technologies on crop yield and N-use efficiency in furrow-irrigated corn fields but did not study their effects on nitrate leaching. Other studies that reported the effects of such fertilizers on nitrate leaching and water quality are under sprinkler irrigation systems (Maharjan et al., 2014; Wilson et al., 2010; Venterea et al., 2011).

The use of advanced fertilizer technologies such as controlled- or slow-release N has shown the potential to mitigate nitrate leaching loss under sprinkler irrigation systems (Venterea et al., 2011), but their potential has not been evaluated under furrow irrigation yet. It is also important to quantify the emission of nitrous oxide (N_2O), one of the potent greenhouse gases, resulting from fertilizer N in agricultural soils and optimize fertilizer N rates and sources to reduce N_2O emissions. The objective of this experiment is to evaluate the effects of different sources and rates of fertilizer N for improved crop grain yield and reduced nitrate leaching and nitrous oxide (N_2O) emissions from corn fields under the furrow irrigation system.

MATERIALS AND METHODS

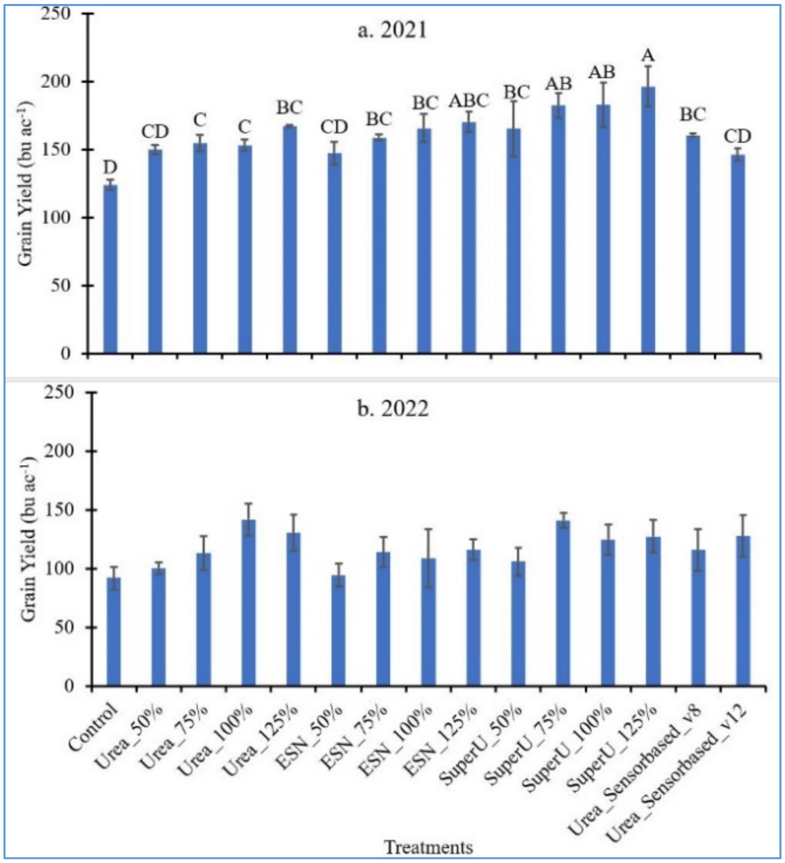
A three-year field experiment was started in a furrow-irrigated corn at the UNL Panhandle Research, Extension, and Education Center in Scottsbluff, NE, in 2021. The experiment was laid out in a randomized complete block design with four replications. The treatments included three fertilizer N sources at four rates (50%, 75%, 100%, and 125% of the recommended N rate based on soil test and yield goal) plus a crop sensor-based N rate applied at V8 and V12 growth stages. The N sources included urea, polymer-coated urea (ESN®), and urea with urease and nitrification inhibitors (SUPERU®). Corn was planted on May 14 in 2021, and May 19 in 2022. All fertilizers were applied at corn emergence except for the sensor-based treatments, where only 30% was applied at emergence and the rest at respective growth stages based on the crop sensing data.

After corn planting, a suction-cup lysimeter was installed at 120 cm depth in selected treatment plots. Lysimeters were left under a vacuum and sampled every week (following irrigation or rainfall events) for water analyzed for nitrate-N. The field was irrigated with the gated-pipe system to provide full irrigation matching the crop water demand. Nitrous oxide fluxes from selected plots were measured weekly using an N_2O analyzer (Li-COR Biosciences, NE). At crop maturity, corn grain was harvested with a plot combine. Postharvest soil samples were collected in all treatment plots and analyzed for nitrate-N.

RESULTS AND DISCUSSION

Corn Grain Yield

In 2021, corn grain yield significantly increased with fertilization compared to control, except for urea and ESN applied at 50% of recommended rate and sensor-based urea application at the V12 growth stage (Figure 1). When averaged across the N rates, grain yield was in order urea with inhibitors (SUPERU) > polymer-coated urea (ESN) = urea >



Control (Figure 2). Grain yield had significant quadratic responses across N ramps for each fertilizer source (Figure 3).

For the second year, there were no significant differences among fertilized treatments which might be due to severe drought conditions early in the season. In addition, the irrigation well was short of water, and we could not irrigate until an alternative source was arranged later in the season. When averaged across the N rates, only urea with inhibitor (SUPERU®) had significantly greater grain yield than the control. Across N ramps for each fertilizer source, grain yield had a significant quadratic response as in 2021, but with a much smaller slope (Figure 3).

Figure 1. Mean corn grain yields (with standard deviation) for different N treatments in (a) 2021 and (b) 2022. Different uppercase letters refer to the significant treatment differences in grain yield at $p < 0.05$. In treatment labels, the number followed by the fertilizer source indicates the applied percentage of recommended N rates.

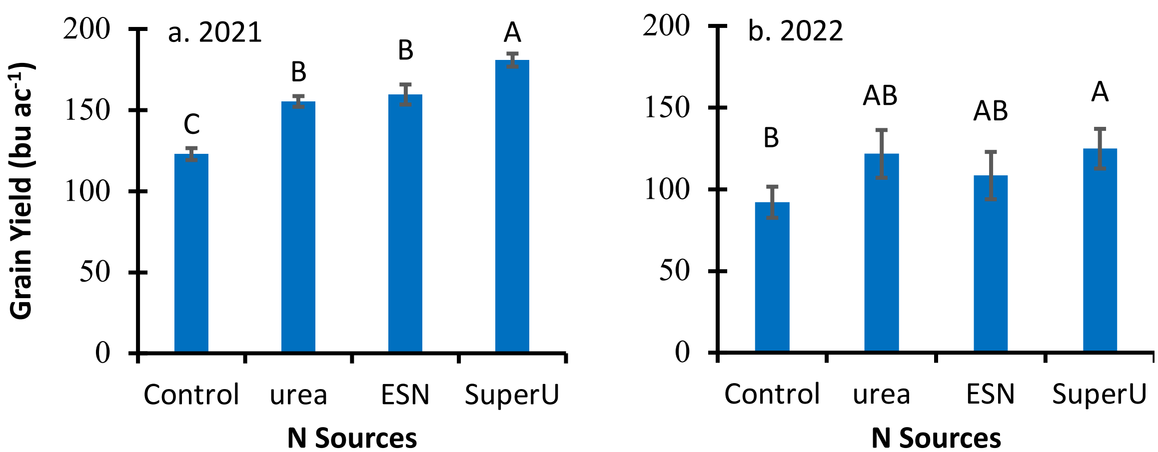


Figure 2. Mean corn grain yield (with standard deviation) averaged across N rates for different N sources in (a) 2021 and (b) 2022. Different uppercase letters refer to the significant treatment differences in grain yield at $p < 0.05$.

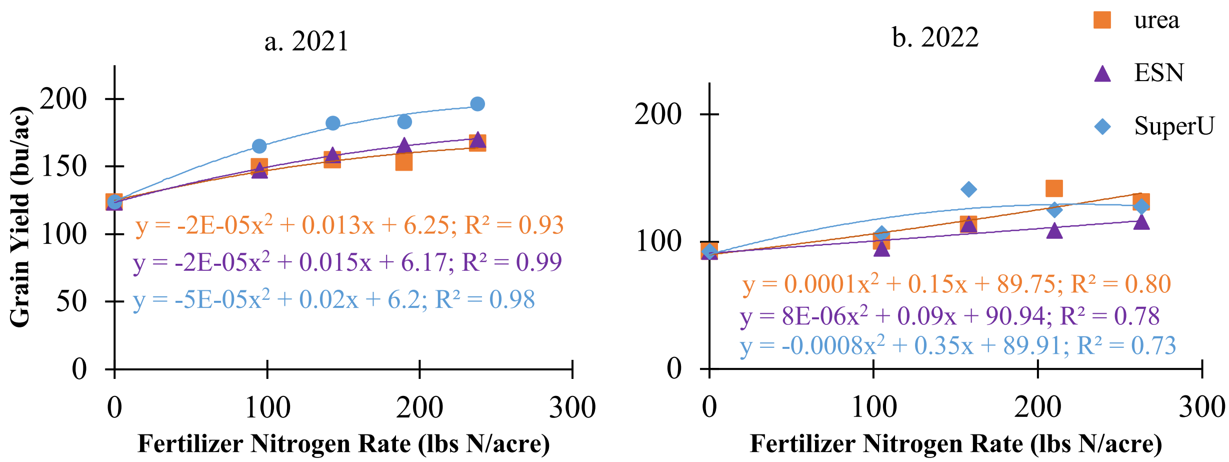


Figure 3. Regression of grain yield against N rates for different N sources in (a) 2021 and (b) 2022. All regression relationships are significant at $p \leq 0.05$.

Nitrate Concentrations in Soil Water

The trends for nitrate concentrations in water samples from lysimeters in 2021 showed an inconsistent pattern across urea-N rates. There were instances where the highest urea-N rate treatment had greater nitrate concentrations than the others, as anticipated. But there were other cases where lower-N rate treatments had greater nitrate concentrations. All urea-N treatments had nitrate concentrations > 10 ppm in more than 1 sampling event. In 2022, nitrate concentrations in water samples were lower than in 2021, which could be potentially due to drought and lower than optimal irrigation. At two sampling events, the highest N rate treatment had nitrate concentration > 10 ppm.

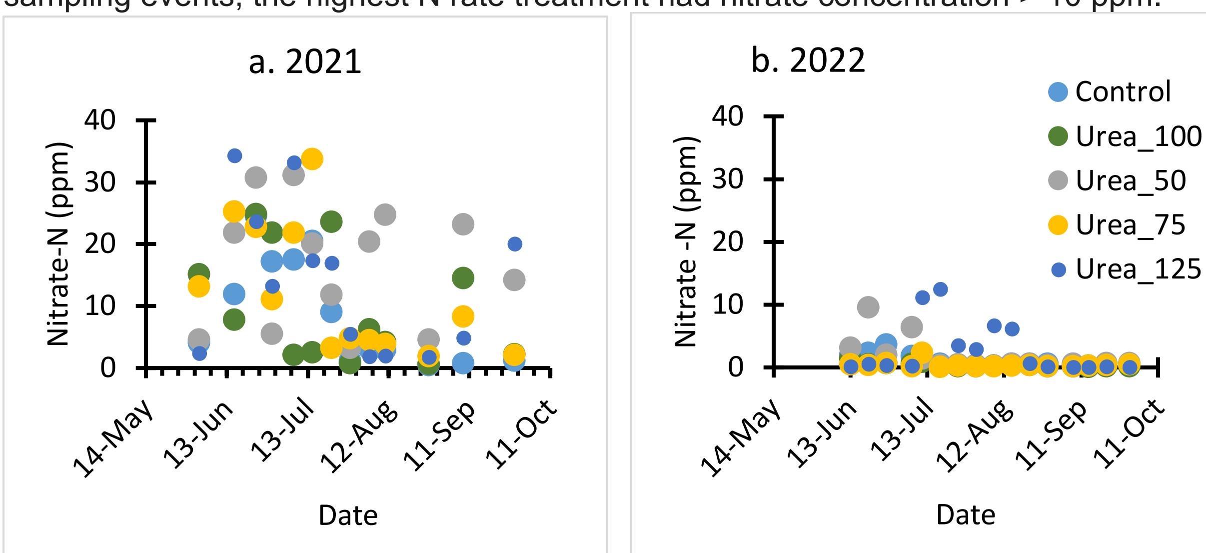


Figure 4. Nitrate-N concentration (ppm) in water samples throughout the growing season under different urea-N rate treatments in (a) 2021 and (b) 2022

Nitrous Oxide Emissions

Nitrous oxide fluxes peaked a month after fertilization. The higher the urea-N rate, the greater the flux was observed. The SuperU and ESN treatments had lower fluxes compared to urea treatments. The ESN treatment had higher fluxes than other treatments later in the season (late July – early August). Overall, the split N application based on sensor data had minimal fluxes throughout the season. Only after mid-September (3 months after fertilizations), the fluxes for all treatments reduced to <20 μgN/m^2/hr.

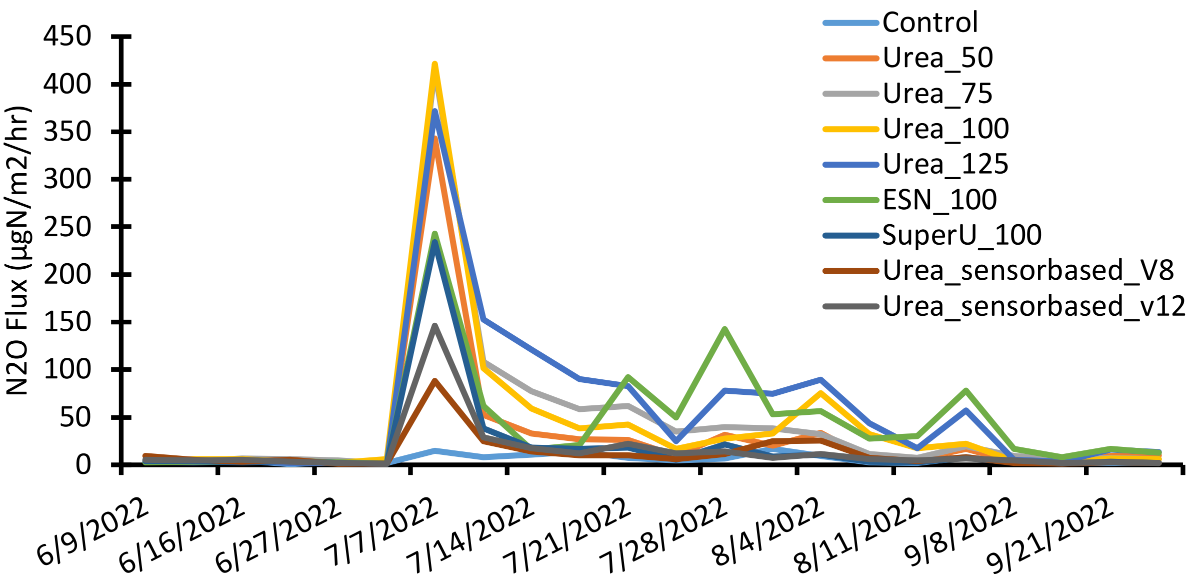


Figure 5. Nitrous oxide fluxes during the growing season of year 2022 for different N treatments. Fertilizers were applied on 06/07/2022 except for crop sensing treatments which received N at V8 (on 07/11/2022) and V12 (on 07/18/2022).

Conclusions

Urea with chemical inhibitors demonstrated yield benefits compared to urea with or without polymer coating. Since irrigation water was applied at full or sub-optimal amounts, drainage water sampling was not always successful. Still, urea rates or use of advantage fertilizer technology needs to further be evaluated to reduce potential leaching losses. Chemical inhibitors tend to reduce N_2O emission loss compared to urea with or without polymer coating. The N treatment based on crop sensing is also a potential tool to reduce N_2O emission and needs further evaluation.

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