IMPROVING CORN GRAIN YIELD AND REDUCING NITRATE-N LEACHING WITH UREASE AND NITRIFICATION INHIBITORS

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ABSTRACT

Sustainable corn (*Zea mays* L.) production requires proper nitrogen (N) management to optimize yield and minimize negative impacts of N losses on water quality. Nitrification inhibitors could be a viable strategy to synchronize N availability and corn N demand and decrease N loss through nitrate-N leaching. A field study was laid out in a randomized complete block design with five replicates at the Belleville Research Center, IL, in 2023, with two fertilizer sources [urease inhibitor (U) & urease and nitrification Inhibitor (N+U)] at eight N rates (0-394 kg ha^{-1}). The objectives were to evaluate the effect of U vs N+U on corn grain yield, economically optimum N rate (EONR), nitrate-N leaching, yield-scaled leaching and N use efficiency. Corn grain yield was similar between U and N+U at lower N rates (0-283 kg ha^{-1}), with EONR of 291 and 152 kg ha^{-1} for U and N+U, respectively. Nitrate-N and yield scaled nitrate-N leaching increased exponentially with N rate, while N+U reduced nitrate-N leaching by 63% and yield-scaled leaching by 50% compared to U. The N use efficiency decreased linearly with increasing N rate for U (19 kg DM kg^{-1} N) but plateaued for N+U (28 kg DM kg^{-1} N). Overall, incorporating N+U inhibitors enhanced N retention and reduced leaching losses without major yield penalties. These findings highlight N+U as a more sustainable N management strategy in corn production systems under variable soil moisture conditions.

INTRODUCTION

Enhanced efficiency fertilizers are designed to improve nitrogen (N) use efficiency and minimize environmental losses by synchronizing N release with crop demand. Among these, urease inhibitors (U) and nitrification inhibitors are two of the most widely adopted strategies. Urease inhibitors slow the enzymatic hydrolysis of urea, thereby reducing ammonia volatilization and improving soil N retention. Nitrification inhibitors, on the other hand, delay the microbial oxidation of ammonium to nitrate, thereby reducing environmental N losses through gradual release of available N aligned with crop uptake. Previous research has demonstrated that nitrification inhibitors can enhance corn grain yield; however, the magnitude of yield response is influenced by crop type, climatic conditions, and soil characteristics (Quemada et al., 2013).The combined use of urease and nitrification inhibitors (N+U) during the corn phase may not only reduce in-season N losses but also delay N transformations, potentially increasing soil N availability. Therefore, the objectives of this study were to evaluate the effects of urease inhibitors (U) and urease + nitrification inhibitors (N+U) on corn grain yield, economically optimum nitrogen rate (EONR), leaching and N use efficiency.

MATERIALS AND METHODS

In 2023, a field experiment was initiated at the Belleville Research Center in Belleville, IL by employing a randomized complete block design replicated five times. Treatments were two fertilizer source -urease inhibitor alone and a combination of urease and nitrification inhibitors applied at eight N rates (0, 62, 117, 172, 228, 283, 339, and 394 kg N ha^{-1}).

The economically optimum rate, representing the rate of N fertilizer recommended for application was determined. A linear plateau model best fits the data. A linear plateau model can be obtained based on the N rate used:

$$y = a + bx \text{ if } x < c \quad (1)$$

$$y = p \text{ if } x \geq c \quad (2)$$

where y is the yield of corn grain (kg ha^{-1}) and x is the rate of N application (kg ha^{-1}); a (intercept), b (linear coefficient), c (critical rate of fertilization, which occurs at the intersection of the linear response and the plateau lines), and p (plateau yield) are constants obtained by fitting the model to the data (Cerrato and Blackmer, 1990).

Ion-exchange resin (IER) lysimeters were used to quantify nitrate-N leaching losses during the growing season (Langlois et al., 2003; Leon et al., 2024; McIsaac et al., 2010; Susfalk and Johnson, 2002). Lysimeters were extracted for nitrate-N using 1M KCl solution at a 1:2 resin mass-to-solution ratio and were analyzed calorimetrically, and the results were expressed on an area basis (kg nitrate-N ha^{-1}). Yield-scaled nitrate-N leaching was determined by dividing the total amount of nitrate-N leached per Mg of corn grain yield (Pittelkow et al., 2017). Nitrogen use efficiency (NUE, kg DM kg^{-1} N) was calculated as (DM yield at a given N rate – DM yield at zero N)/N applied (Ketterings et al., 2007). Data were evaluated for normality of residuals and analyzed using SAS statistical software. Results with $p < 0.05$ were considered significant.

RESULTS & DISCUSSION

Corn grain yield

Corn grain yield was significantly affected by the interaction between N sources and application rates ($p < 0.003$). A linear-plateau model provided the best fit for determining EONR for both sources, which were 291, and 152 for U and N+U, respectively (Fig.1). The lower EONR observed with N+U likely reflects limited nitrate-N availability under limited soil moisture conditions, resulting in an early yield plateau due to physiological N shortage. In contrast, the U treatment may have allowed faster nitrification and greater nitrate-N supply at higher N rates (339-394 kg ha^{-1}). At the EONR corn grain yields were 12,828 and 11,795 kg ha^{-1} for the U and N+U, respectively.

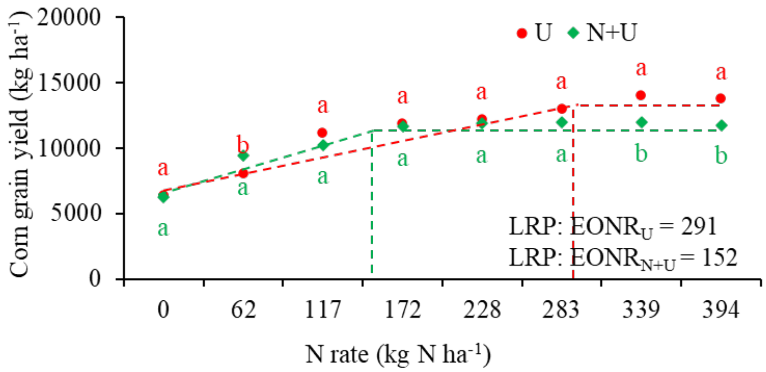

Fig. 1. Interaction of nitrogen (N) source and, N rate on corn grain yield. U: urease inhibitor; N+U: nitrification+urease inhibitor; LRP: linear plateau.

Nitrate-N leaching

Nitrate-N leaching was significantly influenced by N application rates ($p < 0.0001$), where leaching exponentially increased with increase in N rates (Fig.2). At the EONR nitrate-N leaching was 80 and 30 kg ha^{-1} for the U and N+U, respectively indicating that N+U reduced nitrate-N leaching by 63%. This reduction is likely due to the slower conversion of ammonium to nitrate, which decreases the amount of nitrate susceptible to leaching losses.

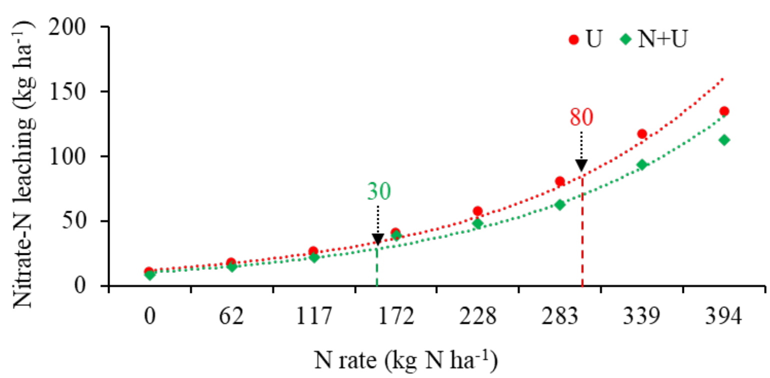

Fig. 2. Interaction of nitrogen (N) source and, N rate on nitrate-N leaching. U: urease inhibitor; N+U: nitrification+urease inhibitor.

Yield-scaled nitrate-N leaching

Exponential model was also the best fit for yield-scaled leaching losses, with significant ($p < 0.0001$) losses above the EONR. Yield-scaled leaching losses were 6 and 3 kg NO_3-N Mg^{-1} for the U and N+U, respectively, indicating a twofold decrease when switching from U to N+U (Fig.3).

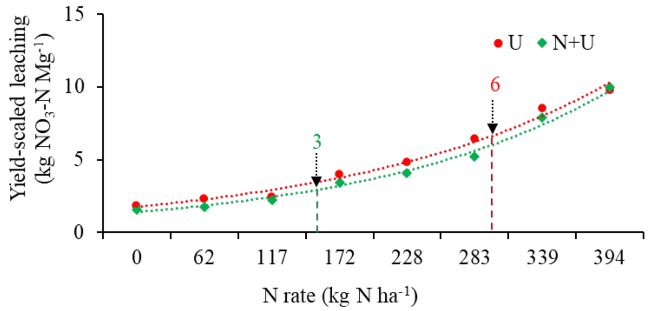

Fig. 3. Interaction of nitrogen (N) source and, N rate on yield-scaled nitrate-N leaching. U: urease inhibitor; N+U: nitrification+urease inhibitor.

Nitrogen use efficiency

Nitrogen use efficiency was significantly affected by the interaction between N sources and application rates ($p < 0.003$) (Fig.4). The N use efficiency linearly decreased with increase in N rate for U, reaching 19 kg DM kgN^{-1} at the EONR. In contrast, NUE followed a quadratic plateau response for N+U, showing the highest efficiency of 28 kg DM kgN^{-1} at EONR. This suggests that U inhibitors alone were less effective in utilizing the fertilized N compared to N+U, which showed higher efficiency at low N rates.

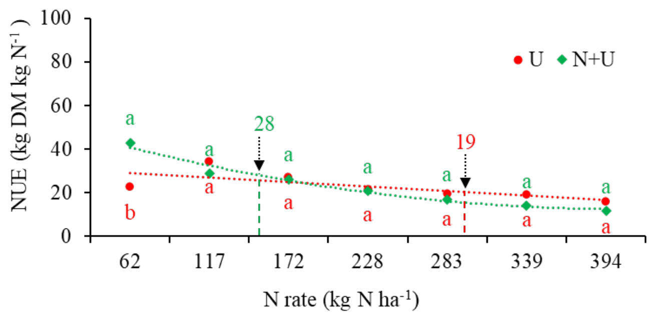

Fig. 4. Interaction of nitrogen (N) source and, N rate on yield-scaled nitrate-N leaching. U: urease inhibitor; N+U: nitrification+urease inhibitor.

Preliminary Conclusion

The combined use of N+U inhibitors improved nitrogen use efficiency and substantially reduced nitrate-N leaching compared with U inhibitors alone. These results suggest that N+U can enhance N retention and environmental sustainability without major yield penalties, particularly under conditions of limited soil moisture where nitrate losses are otherwise high.

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