EVALUATION OF FOLIAR-APPLIED NANO-FERTILIZERS FOR ENHANCED NITROGEN USE EFFICIENCY OF WHEAT

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OBJECTIVE

The goal of this study is to assess the N use efficiency and environmental impacts of foliar N application with and without nanocarriers. Our specific objectives are to:

Determine the effect of foliar UAN and urea applications relative to soil applications on wheat yield, N uptake, and N use efficiency at a low and recommended N rate.

Compare the wheat yield, N uptake, and N use efficiency of foliar-applied UAN and urea with nanocarriers to foliar-applied UAN and urea without nanocarriers at a low and recommended N rate.

Quantify N losses, including nitrate leaching, nitrous oxide emissions, and ammonia volatilization for the different N sources and delivery methods at the recommended N rate.

METHODS & MATERIALS

During the 2023-2024 wheat growing season at Spindletop Farm in Lexington, we evaluated two common nitrogen fertilizer sources – urea and urea ammonium nitrate (UAN) applied to the soil and to the foliage. The N fertilizer source and application methods included in our study are listed below (Table 1). We applied these treatments at three rates – 0, 50, and 100 lb N/acre. The applications were split applied with 30% at Feekes 3, 30% at Feekes 5/6, and 30% at Feekes 8. The study design was a randomized complete block design in which the combinations of N rate, source, and application method were randomized within each of four replicate blocks. The plots were 5 ft wide by 15 ft long. However, for the plots receiving the experimental nanocarrier for urea, the applications were made over the central 3 ft by 10 ft of the plot due to limited supply of the material, while the remainder of the plot received the same N rate as granular urea.

The field study was conducted in a field that had been harvested as high moisture grain. Muriate of potash was applied on October 10, 2023 at 100 lb K_2O/acre according to soil test results. On October 18, 2023, Pembroke 2021 wheat was planted at 120 lb seed/acre and a depth of 1.5 inches. Nitrogen fertilizer applications were made on March 7 (Feekes 3), March 28 (Feekes 6), and April 13 (Feekes 8). We used UAN with 28% N and urea solutions with 2% N. Liquid applications were done using a CO_2 backpack sprayer while granular urea was applied to the soil by hand. Silwet L-77 was included with urea solutions to aid in leaf penetration of fertilizer. The wheat also received an application of Harmony Extra for weed control on March 14, 2024 and Caramba for disease control at anthesis on May 2, 2024. Following wheat harvest, double crop soybeans (AG42XF4) were planted on June 26, 2024 at 200,000 seeds/acre on 15 inch rows.

Soil samples for inorganic N were collected at 0-4, 4-8, and 8-16 inches just prior to planting on October 17, 2023, at the time of greening up on February 26, 2024, at the time of heading on April 29, 2024, and after harvest on June 24-25, 2024. Passive lysimeters were installed at a depth of 1.25 ft prior to wheat planting to capture leachable nitrate. The lysimeters will be removed and analyzed following harvest of double crop soybeans in fall of 2024. In addition, we measured nitrous oxide emissions throughout the entire growing season of wheat and double crop soybeans. The preparation of lysimeters and greenhouse gas sampling equipment took more time than expected, and we were not able to install equipment to measure ammonia volatilization. All of the measurements of N losses were collected in the plots receiving 100 lb N/acre. In addition, photos were taken of each plot every two weeks to assess potential leaf damage due to N applications. Wheat biomass samples were collected from a 1 m2 area within each plot at full maturity. The grains, chaff, and straw were weighed and are being prepared for N analysis to determine N uptake and N use efficiency.

RESULTS AND DISCUSSION

To date, we have completed data collection for grain yield and wheat aboveground biomass as well as nitrous oxide emissions for the wheat growing season. We present yield and nitrous oxide results below (Figures 1-3). The aboveground biomass results show the same treatment effects as the yield results, so we have not included graphs of those results. We have also viewed the wheat photos and determined that leaf damage was not an issue for any applications during the 2023-2024 season. The plant N uptake, soil inorganic N, and nitrate leaching measurements are still in progress.

Regarding our first objective, we determined that foliar application had no effect on wheat grain yield relative to soil application (Figure 1). In addition, wheat yielded similarly with UAN or urea. Considering the traditional fertilizer treatments (i.e., excluding the nanocarriers), the only significant factor affecting yield was N rate, with 100 lb N/acre resulting in the highest yields (Figure 1).

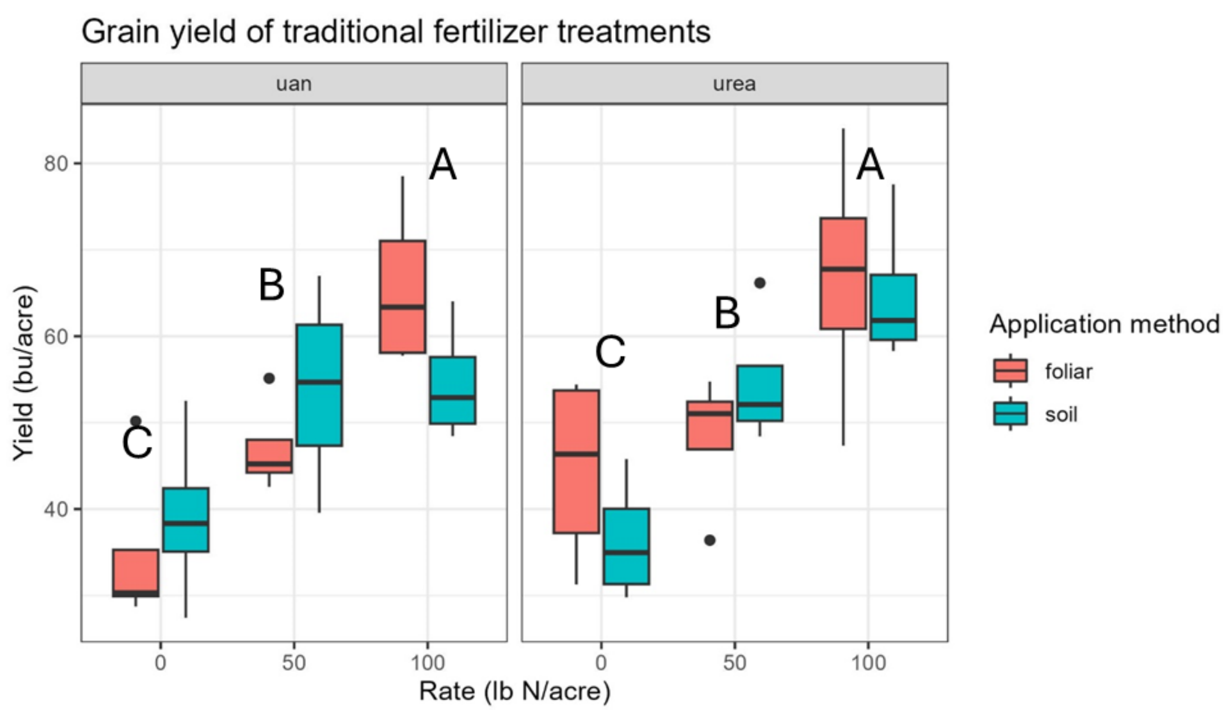

Figure 1. Boxplots showing wheat yield response to N rate and application method for each source UAN – left; urea – right) in Lexington, KY 2023-2024. The different capital letters indicate differences among N rates averaged across the application methods for each of the N sources ($p<0.05$).

We also wanted to compare the wheat yield of foliar-applied UAN and urea with nanocarriers to foliar-applied UAN and urea without nanocarriers at different N rates. For this objective, we found that the wheat responded positively to N rate for all treatments but not the nanocarrier controls (Figure 2). However, the nanocarriers with N ('uan-nano' and 'urea-nano') were not significantly different from the traditional fertilizers ('uan' and 'urea') (Figure 2, right plot). The nanocarrier controls, which consisted of the nanocarriers without any N loaded on them, all yielded low and like the 0 lb N/acre treatments (Figure 2, left plot), indicating that the nanocarriers on their own did not impact wheat yield.

In terms of the environmental impact of our treatments, we observed significantly lower nitrous oxide emissions for all of the foliar applications ('Urea Foliar', 'UAN Foliar', 'Urea Nanocarrier', 'UAN nanocarrier') as compared to the soil applications (Figure 3).

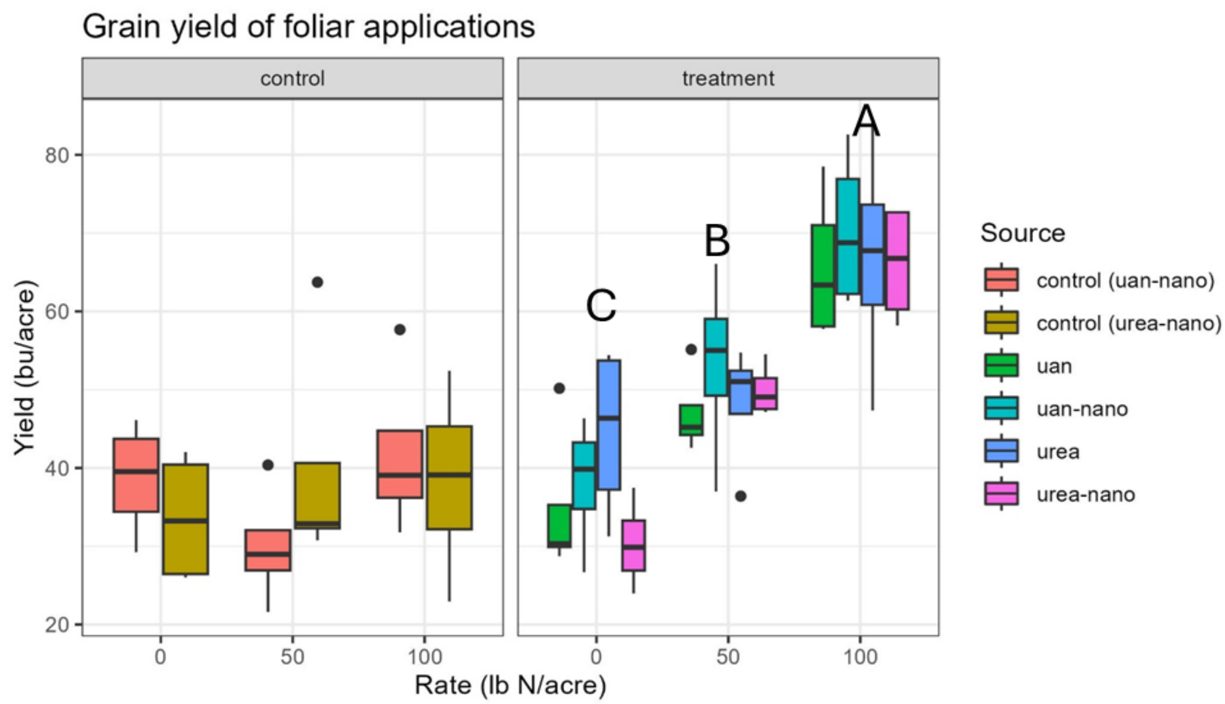

Figure 2. Boxplots showing wheat yield response to N rate and source for the foliar application method in Lexington, KY 2023-2024. The controls shown on the left plot consist of nanocarriers that did not include N but were applied at rates that provided the same amount of nanoparticles as the nanocarrier treatments that contained N. The different capital letters in the right plot indicate differences among N rates averaged across the N sources ($p<0.05$).

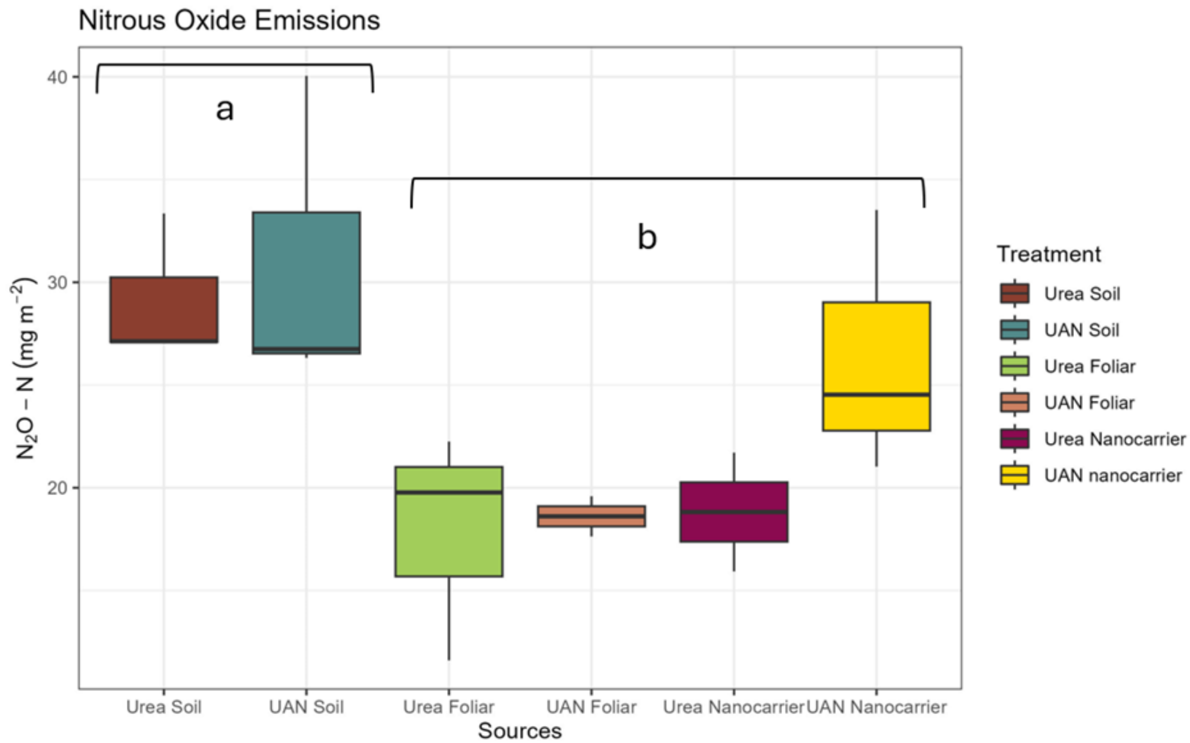

Figure 3. Boxplots showing cumulative nitrous oxide emissions for each fertilizer treatment applied at 100 lb N/acre during the wheat growing season in 2023-2024. Different lowercase letters indicate significant differences between the bracketed treatments.

CONCLUSION

Overall, our results from the first year of this research indicate that the source, application method, and use of nanocarriers has negligible impact on the productivity of wheat. However, we were intrigued to find a significant effect of application method on the nitrous oxide emissions. We believe that the lower emissions associated with foliar applications can be attributed to the reduced interaction of fertilizer N with soil microbes, which are responsible for producing this gas. To our knowledge, we are the first to evaluate the effects of foliar application on nitrous oxide emissions in wheat. Although the absolute amount of N lost as nitrous oxide is small from an agronomic perspective, it is environmentally consequential because nitrous oxide is such a powerful greenhouse gas. Further research is needed, but our preliminary findings suggest that a relatively easy change - applying UAN to the foliage rather than soil – could improve environmental quality without negative effects on wheat yield.

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