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Assessing the Impact of the 4R Nutrient Management on Nitrogen Use Efficiency in Corn

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Summary
Determining the best management practices for nitrogen (N) fertilizer application to corn is crucial to achieving the objectives of the 4R of nutrient stewardship. Although producers have a wide range of options regarding N fertilization, identifying the right rate, source, placement, and timing (4R) can significantly impact productivity and nitrogen use efficiency. Our objectives were to evaluate the nitrogen agronomic efficiency (NAE), and the corn grain yields as affected by different rates, sources, placements, and timing methods of N fertilizer application under rainfed and irrigated conditions in Kansas. Two rainfed locations in Riley and Republic counties and two irrigated locations in Republic and Shawnee counties were established in 2021. Increasing rates from 0 to 180 lb N/a in 30-lb increments for rainfed locations and 0, 90, 120, 150, 180, 210, 240 lb N/a for irrigated locations were applied at planting, as broadcast urea. Additionally, five different N management treatments were applied at the same rate of 90 and 120 lb N/a for rainfed and irrigated locations, respectively. The nitrogen application significantly impacted the grain yield for both irrigated and rainfed locations. Applying N fertilizer as UAN coulter-injected at planting and SUPERU (Koch Agronomic Services, LLC) at side-dress V6 growth stage increased grain yield and AE across locations when compared to the baseline of urea broadcast at planting.

Introduction
The "4R" references the four rights of nutrient management practices: right source, right rate, right time, and right place (Fixen, 2020). Nitrogen fertilizer inputs are generally necessary for optimizing corn yields, but N is the most challenging plant nutrient to manage optimally (Ransom et al., 2020). There is a significant opportunity for reducing N losses associated with management practices (Shanahan et al., 2008). Enhancing N use efficiency is crucial to maintain and improve productivity and sustainability in agriculture. Ideal N management optimizes grain yield and N use efficiency (Shapiro and Wortmann, 2006). Our objectives were to evaluate the nitrogen agronomic efficiency (NAE), and the corn grain yields as affected by different rates, sources, placements, and timing methods of N fertilizer application under rainfed and irrigated conditions in Kansas.

Procedures
The study was conducted during the 2021 corn growing season across Kansas. Two irrigated locations in Republic and Shawnee counties and two rainfed locations in

Republic and Riley counties were established under a randomized complete block design with five replications; plots were 10-ft width × 40-ft length. N fertilizer was applied at planting using urea as source, in the irrigated locations at rates of 0, 90, 120, 150, 180, 210, and 240 lb N/a, and in the rainfed locations at increasing rates from 0 to 180 lb N/a in 30-lb increments were applied by broadcasting the fertilizer. Additionally, five different N management treatments, broadcast urea + NBPT, streamed UAN and UAN coulter-injected at planting, side-dress SUPERU and streamed UAN at V6 corn growth stage were applied at the same rate of 90 and 120 lb N/a for rainfed and irrigated locations, respectively. Before planting, soil composites samples were collected by block at 0 to 6 and 0 to 24 in. depth using hand probes. Corn was planted from April 25 to May 5. Plant and grain samples were collected from six plants from middle rows when corn reached the R6 maturity growth stage; samples were dried at 140°F (60°C) and ground to 2 mm. N content in the plant and grain were determined through dry combustion. Yields were determined by harvesting the two middle rows from each plot and correcting grain moisture to 15.5%. Nitrogen agronomic efficiency (NAE) was calculated as:

$$NAE = \frac{Y_N - Y_{0N}}{F}$$

Where Y_N represents the grain yield (lb/a) obtained from the N fertilized plots, Y_{0N} represents grain yield (lb/a) obtained from the plots with 0 lb N/a, and F represents the amount of N fertilizer applied (lb N/a).

Analysis of variance (ANOVA) and Fisher's least significant difference (LSD) pairwise comparisons at $\alpha < 0.1$ were performed using the RStudio 2022.07.2+576 software.

Results

Corn Grain Yield

There was a significant yield increase in grains due to the application of nitrogen across both irrigated (Figure 1A) and rainfed (Figure 1B) locations. The agronomic optimum nitrogen rate (AONR) was calculated for both irrigated and rainfed crops using the quadratic regression, for irrigated locations an AONR of 230 lb of N/a was obtained, and a value of 204 lb of N/a for rainfed locations. The nitrogen management treatments increase grain yields across rainfed locations (Figure 2B) compared to the urea baseline at planting. Across irrigated locations the UAN coulter-injected at planting and the SUPERU side-dress at V6 growth stage, significantly increased the grain yields ($P < 0.07$) when compared to the baseline urea (Figure 2A).

Nitrogen Agronomic Efficiency

The higher rates of N fertilizer significantly decrease the NAE across both irrigated (Figure 3A) and rainfed (Figure 3B) locations. Nitrogen agronomic efficiency decreased with the N rate increases as expected, particularly for excessive N rates (Wortmann et al., 2011; Ruiz Diaz et al., 2012; Halvorson and Bartolo, 2014). The lowest NAE value was obtained with the highest rate of N ($P < 0.0001$). The UAN coulter-injected at planting and the SUPERU side-dress at the V6 growth stage showed the highest NAE values when compared to the baseline of urea broadcast at planting across locations under irrigation (Figure 4A). Across the rainfed locations the trends were similar, with the highest NAE attained with the UAN streamed at planting (Figure 4B).

Acknowledgments

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Table 1. Experimental locations, soil type, pH, organic matter, and mineral nitrogen before planting and treatment application

				0–6 in.		0–24 in.	
County	System	Planting date	Hybrid	pH	OM	NO_3^-	NH_4^+
					%	------lb/a------	
Republic	Irrigated	5/5/2021	P1828AM	6.06	2.90	6.91	33.8
Shawnee	Irrigated	4/29/2021	P1185	6.78	2.34	18.14	27.36
Republic	Rainfed	5/5/2021	P1828AM	4.84	3.02	35.28	51.98
Riley	Rainfed	4/28/2021	P1151AM	5.90	2.15	58.9	33.8

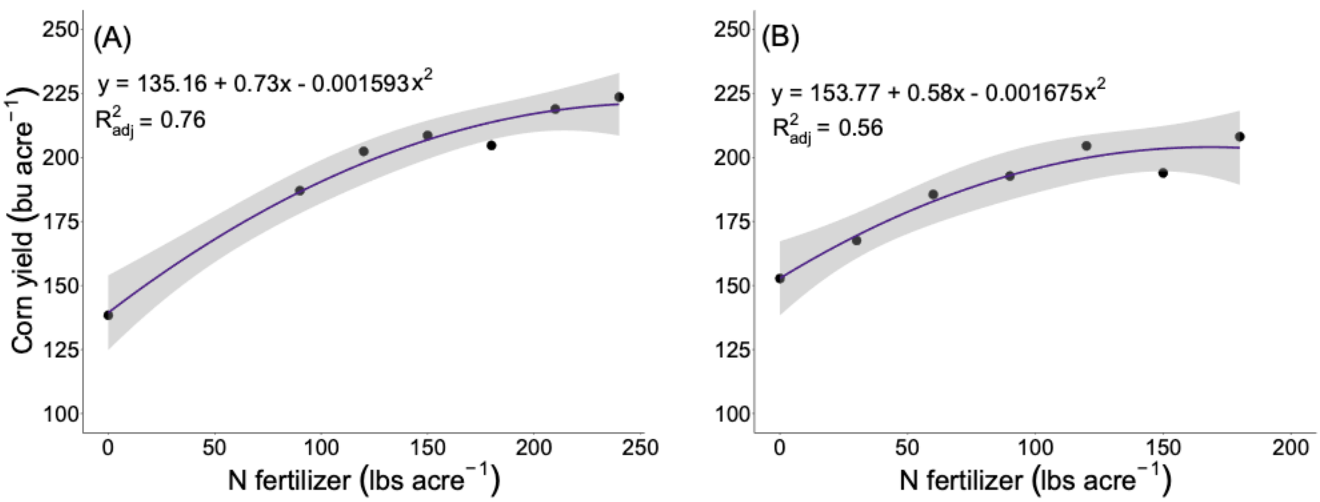

Figure 1. Average corn grain yield (bu/a) as affected by the N rate treatments (lb N/a) across irrigated (A) and rainfed (B) locations.

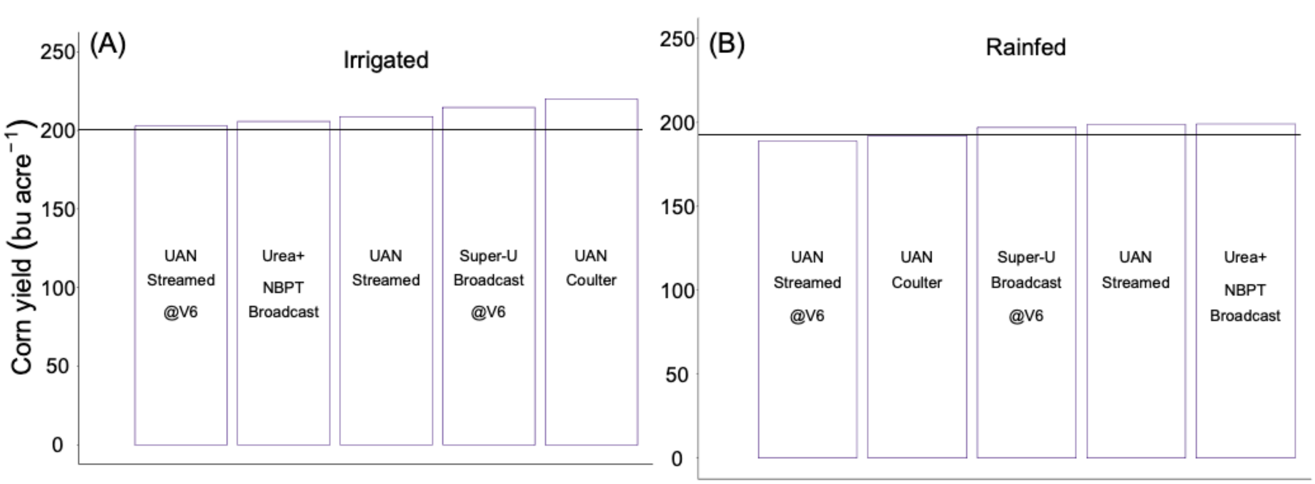

Figure 2. Average corn grain yield (bu/a) as affected by N fertilizer management treatments (lb N/a) across irrigated (A) and rainfed (B) locations. The horizontal line indicates the yield attained with the urea broadcast application method.

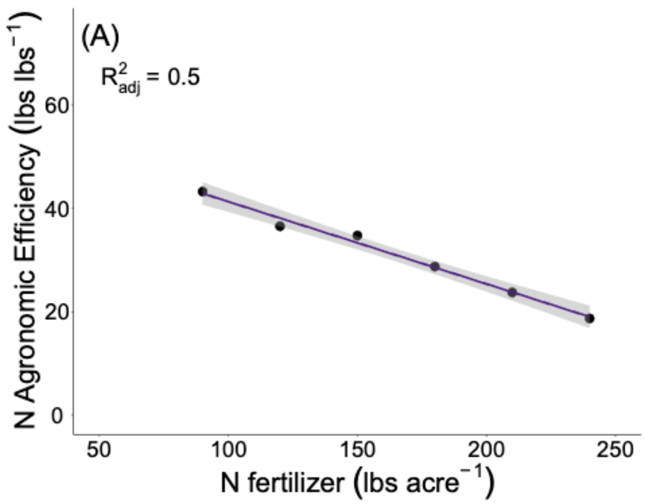

Figure 3. Average N agronomic efficiency (NAE) represented in lbs lbs^{-1} as affected by N fertilizer rate treatments (lb N/a) across irrigated (A) and rainfed (B) locations.

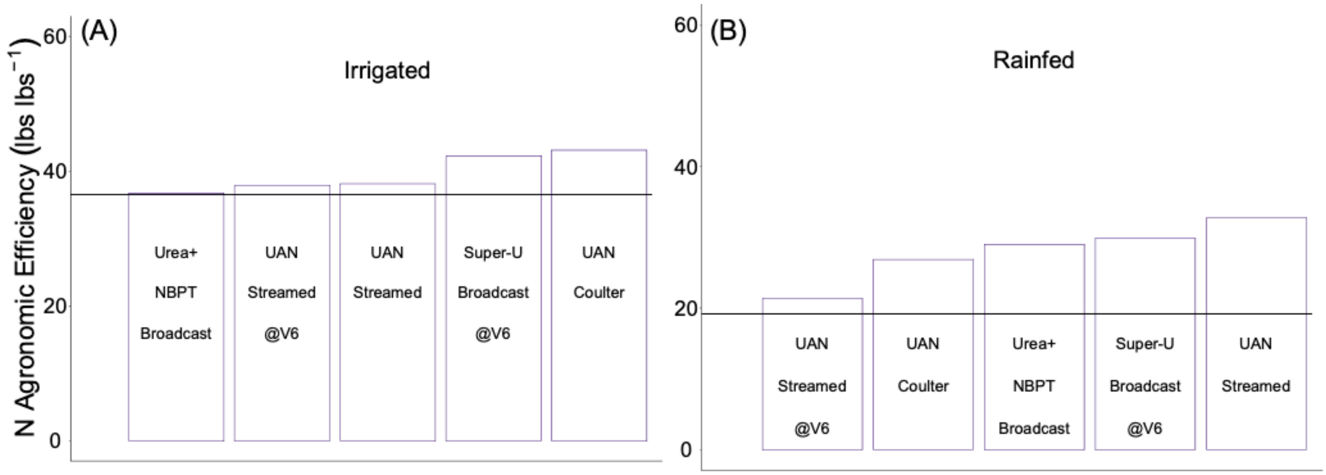

Figure 4. Average N agronomic efficiency (NAE) represented in lbs lbs^{-1} as affected by N fertilizer management treatments (lb N/a) across irrigated (A) and rainfed (B) locations. The horizontal line indicates the yield attained with the urea broadcast application method.