NITROGEN FERTILIZER RATES AND NITRIFICATION INHIBITOR IMPACT ON AGRONOMIC AND ECONOMIC RETURNS IN CORN PRODUCTION IN KANSAS

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ABSTRACT

Nitrogen (N) is an essential nutrient for corn crops. Nitrification inhibitors (NI) aim to increase yields, promote Nitrogen Use Efficiency (NUE), and reduce N losses. This study was carried out in ten site-years in Kansas from 2017-2021 crop seasons, with the objectives of evaluating and comparing the agronomic and economic optimum N rates (AONR, EONR), N uptake in the grains, N agronomic efficiency (NAE) and maximum return to N (MRTN) in corn production with and without the use of NI. Nitrogen fertilizer at the rates of 100, 150 and 200 lbs. N a^{-1} using anhydrous ammonia (AA) as source was applied to the soil with and without the combination of NI (nitrapyrin) in the spring, also a treatment with 0 lbs. N a^{-1} without NI was used as control. AONR and EONR values were lower with the use of NI, higher N grain uptake was obtained when 150 lbs. N a^{-1} was applied with NI combination, and nitrification inhibitor contributes to obtaining a higher average net return to nitrogen fertilizer over multiple site-years.

INTRODUCTION

Nitrogen (N) fertilizer application is necessary to maximize corn yield; however, it is difficult to precisely supply enough N to meet crop requirements while also controlling the risk of N losses to the environment (Cassman and Doberman, 2022). While N rates lower than the optimum will increase the risk of lower yields, N rates above the optimum will cost more, may not offer additional yield, and could be lost (Kranz, 2015). The agronomic optimum N rate (AONR) represents the amount of fertilizer N required to maximize yield, but not necessarily profit (Camberato et al., 2021), the economic optimum N rate (EONR) is defined as the N rate that makes the most effective use of N on a monetary basis, being dependent to the economic environment (Oglesby et al., 2022). Both AONR and EONR are terms used to develop N rate recommendations based on data-driven on-field trials, aiming to increase nitrogen use efficiency.

The return to N (RTN) represents the profit obtained from N at each N rate, the maximum return to N (MRTN) is the highest yield increase from adding N just paid for the N added (Fernandez et al., 2012).

Nitrogen use efficiency (NUE) is defined as the ratio of the crop nitrogen uptake to the total input of N fertilizer (NRCS/USDA, 2007). Increasing N rates are often associated with progressively lower corn NUE values (Ciampitti and Vyn, 2011). A management practice option to reduce N losses during crop production and increase the NUE is using nitrification inhibitors (Omonode and Vyn, 2013). Nitrogm inhibitors are substances developed to reduce the process of nitrification and keep N available for plant uptake for a longer time, especially during the highest crop demands (Corrochano-Monsalve et al., 2021). The objectives of this study were to evaluate and compare the agronomic and economic optimum N rates (AONR, EONR), N uptake from the grains, N agronomic efficiency (NAE) and maximum return to N (MRTN) in corn production with and without the use of nitrification inhibitor under field conditions in Kansas.

MATERIALS AND METHODS

Field studies were conducted from 2017 to 2021 crop growing seasons in 10 site-years in Kansas (Table 1). Nitrogen fertilizer at the rates of 100, 150 and 200 lbs. N a^{-1} using anhydrous ammonia (AA) was applied to the soil with and without the combination of a nitrification inhibitor (nitrapyrin – N Serve®) in the spring. A control treatment was included with no N application. The experimental design was a randomized complete block with four replications. Soil composite samples were collected using hand probes by block at 0-6 and 0-24 in depths before planting.

Plant and grain samples were collected from six plants from middle rows when corn reached R6 maturity growth stage; samples were dried at 140°F (60°C) and ground to 2 mm. N content in the plant and grain was 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 (lbs. a^{-1}) obtained from the N fertilized plots, Y_{0N} represents grain yield (lbs. a^{-1}) obtained from the plots with 0 lbs. N a^{-1}, and F represents the amount of N fertilizer applied (lbs. N a^{-1}).

Analysis of variance (ANOVA) using function lmer from lme4 package and pairwise comparisons using function cld from multcomp package at $\alpha < 0.05$ was performed using the RStudio 2023.09.1+494 software version.

To determine the agronomic and economic optimum rates, quadratic regressions were performed. To determine economic parameters corn price of \$4.95 bu^{-1}, nitrogen price of \$400 ton^{-1} of anhydrous ammonia and nitrogen inhibitor price of \$0.038 lbs^{-1}. per each lb. of nitrogen fertilizer were used.

RESULTS AND DISCUSSION

Corn Grain Yield

Corn grain yield was affected by the nitrogen rates, obtaining higher yields with the higher rates. The AONR value obtained with the use of the inhibitor (156 lbs. N a^{-1}) was lower than the obtained without the use of the inhibitor (170 lbs. N a^{-1}). Also, EONR value with the inhibitor (138 lbs. N a^{-1}) was lower than that obtained without using the inhibitor (149 lbs. N a^{-1}). Results indicate that using the nitrification inhibitor corn grain yield could reach an agronomic and economic maximum using less amount of N fertilizer.

Nitrogen Agronomic Efficiency and Corn Nitrogen Uptake

Grain nitrogen uptake shows similar results to the obtained with the grain yield, at the rate of 150 lbs. N a^{-1} uptake increases significantly with the use of the inhibitor (Figure 2). The nitrogen agronomic efficiency decreases with higher N rates. At the rate of 150 lbs. Numerical advantages, but not significant, were observed with the inhibitor at the rates of

100 and 150 lbs. N a^{-1}, at the rate of 200 lbs. N $a^{-1,}$ there was no difference with or without the use of the inhibitor, suggesting that the potential effectiveness of the product might disappear with higher N rates (Figure 3).

Maximum Return to Nitrogen

The maximum return to nitrogen was affected by corn-to-nitrogen price ratios with the nitrification inhibitor (Figure 4). The use of the inhibitor contributes to obtaining a higher average net return to nitrogen fertilizer over multiple site-years.

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

Site-year	County	Soil	Texture	Planting Date	0-6 in pH	0-6 in OM	0-24 in NO_3^-	0-24 in NH_4^+
						%	lbs. a^{-1}	
1	Riley	Smolan	Silt Loam	4/24/17	7.3	1.8	22.6	55.8
2	Republic	Hastings	Silty Clay Loam	4/25/17	5.8	3.3	31.3	50.2
3	Riley	Smolan	Silt Loam	4/28/18	8.0	1.9	105.2	44.0
4	Shawnee	Eudora	Silt Loam	5/07/18	6.9	1.4	16.8	-
5	Riley	Smolan	Silt Loam	5/25/19	5.7	1.6	43.0	12.0
6	Shawnee	Eudora	Silt Loam	4/25/19	6.6	1.5	13.2	11.6
7	Riley	Belvue	Silt Loam	4/30/20	6.5	2.2	15.5	28.0
8	Shawnee	Eudora	Silt Loam	4/23/20	6.4	1.3	30.4	29.6
9	Riley	Belvue	Silt Loam	4/28/21	5.9	1.7	29.5	35.9
10	Shawnee	Eudora	Silt Loam	4/29/21	7.5	2.1	29.3	36.2

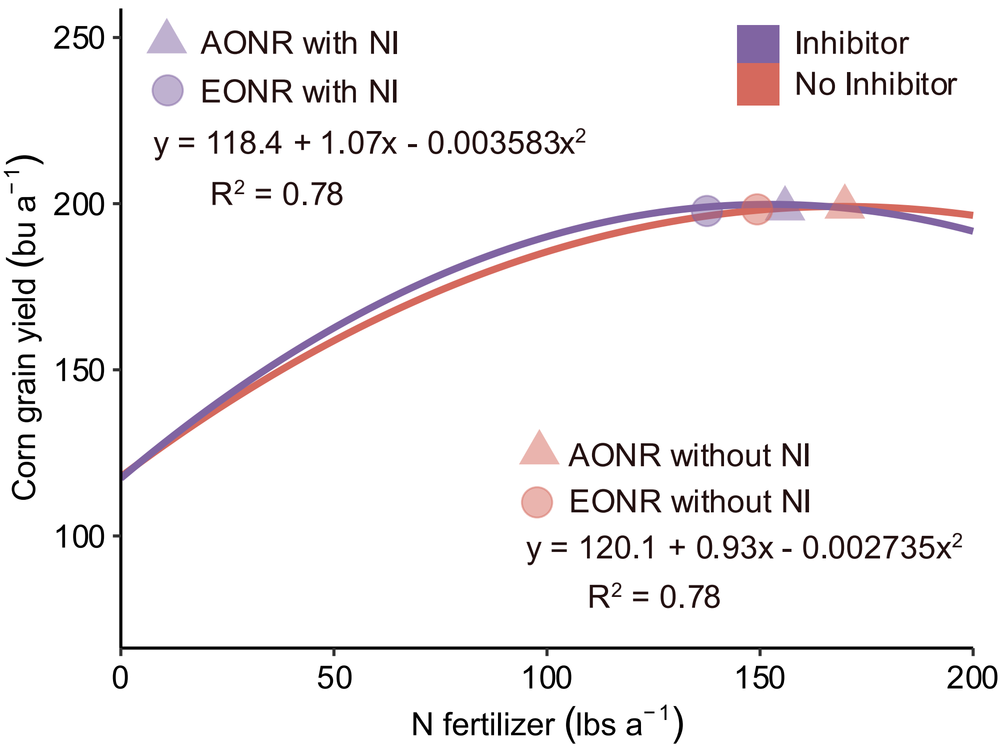

Figure 1. Agronomic optimum nitrogen rate (AONR) and economic optimum nitrogen rate (EONR) with and without nitrification inhibitor. EONR at 13 corn:N price ratio (\$4.95 bu^{-1} corn : \$0.38 lb^{-1} N) without inhibitor, and at 11.84 corn:N price ratio (\$4.95 bu^{-1} corn : \$0.38 lb^{-1} N + \$0.038 NI) with inhibitor.

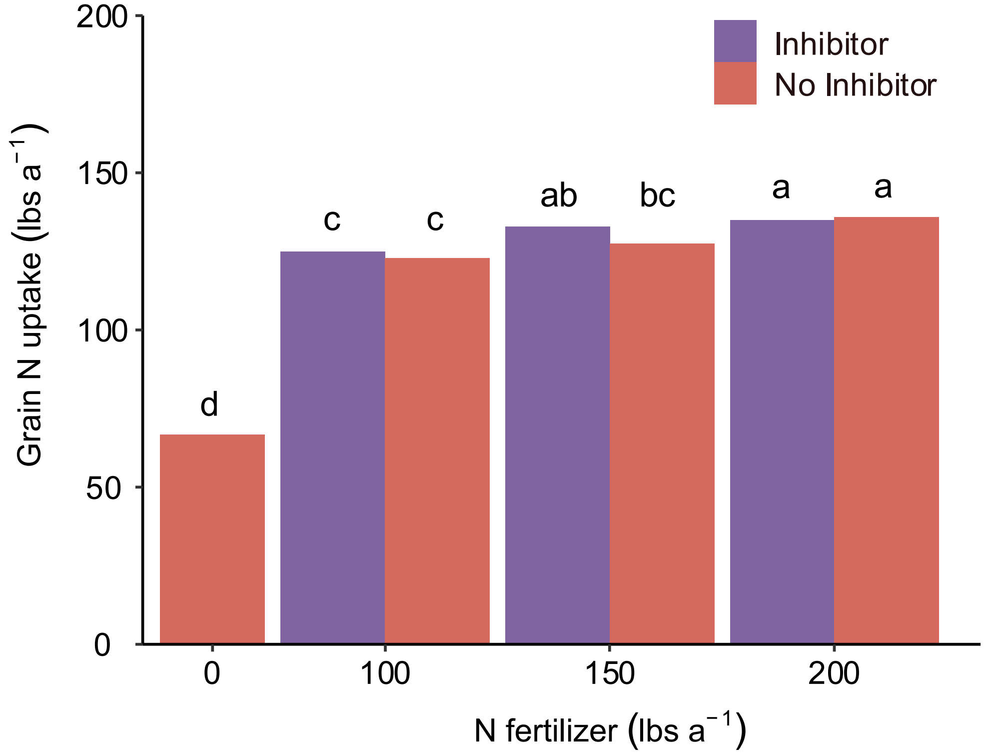

Figure 2. Corn grain N uptake as affected by nitrogen rates and nitrification inhibitor. Means followed by different lowercase letters indicate significant differences ($\alpha = 0.05$).

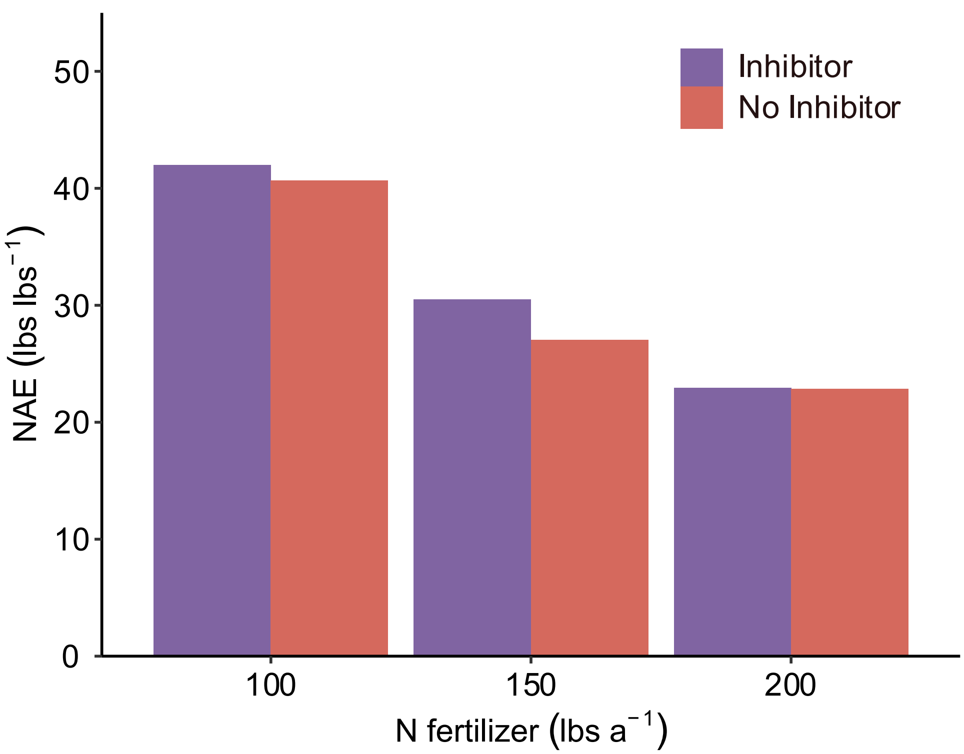

Figure 3. Nitrogen agronomic efficiency (NAE) as affected by nitrogen rates and nitrification inhibitor.

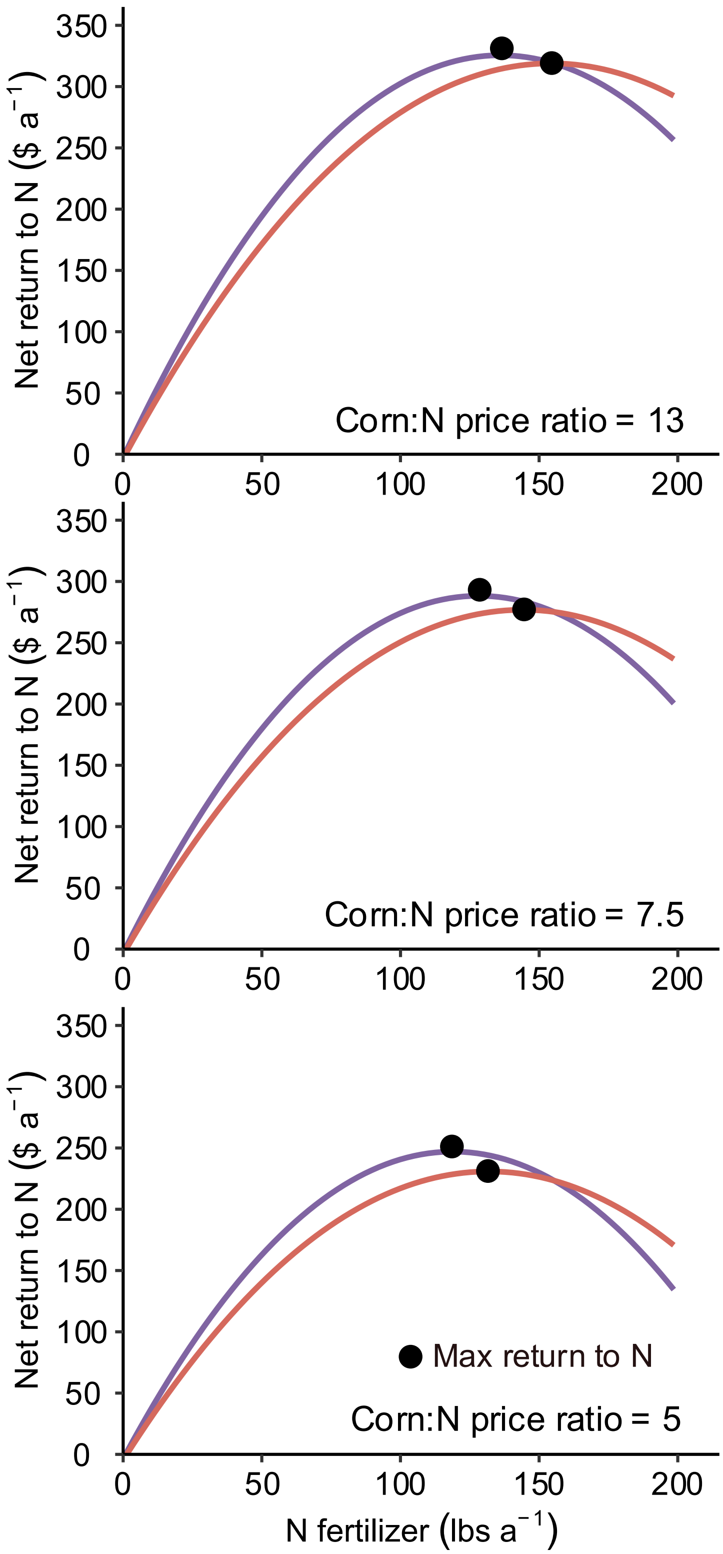

Figure 4. Net return to nitrogen fertilizer under different corn to nitrogen price ratios with and without the use of the nitrification inhibitor.