IN-SEASON CHANGES OF SOIL MINERAL NITROGEN WITH NITROGEN FERTILIZER AND NITRIFICATION INHIBITOR IN CORN

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ABSTRACT

Understanding the role that soil mineral nitrogen (SMN) plays in the growth and productivity of corn is crucial. Nitrogen (N) demands vary during the growing season, and maintaining a sufficient amount of N in the form of ammonium (NH_4^+), or nitrate (NO_3^-) during the peak times of plant N uptake can help support high yields. The objective of this study was to assess changes and the supply of soil mineral nitrogen during the growing season in corn under field conditions in Kansas. This study was carried out in 8 site-years across Kansas during the 2017, 2018, 2019, and 2020. Fertilizer rates included 100, 150, and 200 lbs N acre^{-1} in addition to a control and with and without the use of a nitrification inhibitor at the 150 lbs N acre^{-1} rate. Since the V2 through the R6 grow stage in corn, soil samples were collected every two to three weeks. Samples were collected at 0-12 and 12-24 inches and analyzed for NO_3^- and NH_4^+. Soil NO_3^- concentration showed an initial increase followed by a rapid decrease after the V8 growth stage. This trend was likely due to the initial nitrification process from N fertilizer followed by a rapid corn N uptake. Soil $NH_4^+$was generally higher early in the season, with slightly higher values with the use of nitrification inhibitors. This study indicated that the delayed nitrification process with nitrification inhibitors was detectable with regular soil sampling. However, differences were small, and under regular field production systems is unlikely this small effect will be detectable with soil sampling. Results from this study also provided field values for SMN during the growing season under corn production. Weather and soil variables for each location in this study will be explored to investigate the interaction of soil, weather, and SMN under field conditions.

INTRODUCTION

Once applied to the soil with the fertilizer, nitrogen comes to be part of the soil pool, and changes in forms can occur rapidly. After nitrification, the NO_3^- form can be lost by leaching or denitrification. The amount of NO_3^- that can be lost depends on many variables like the amount of nitrate present in soil solution, the amount of N applied as fertilizer, the nitrification and denitrification rates, as well as weather and soil factors (Cameron et al., 2013).

Corn yield is largely determined by N fertilization and the efficient use of the fertilizer applied. Therefore, developing management and methods to prevent N losses is necessary to improve productivity and avoid possible negative impacts on the environment. Nitrification Inhibitors (NI) were developed to reduce the process of nitrification and keep N in the NH_4^+ form for a longer period of time and available for crop absorption, especially during the highest demands (Corrochano-Monsalve et al., 2021).

The objective of this study was to assess changes and the supply of soil mineral nitrogen during the growing season in corn under field conditions in Kansas.

MATERIALS AND METHODS

Field studies were conducted during the 2017, 2018, 2019 and 2020 corn growing seasons in eight site-years in Kansas. Nitrogen fertilizer was applied in the spring (March) at the rates of 100, 150, and 200 lbs N acre^{-1} using Anhydrous ammonia (AA) with and without the use of a nitrification inhibitor (nitrapyrin) for the rate of 150 lbs N acre$_{-}^{1}$. A control treatment was included with no nitrogen application. The experimental design was a randomized complete block with four replications. Corn was planted from April 23th to May 25th. Composite soil samples were taken at the V2, V4, V6, V8, V12, R1, and R6 corn growth stages at two soil depths, 0-12 and 12-24 inches. Soil NO_3^- and NH_4^+ concentrations were determined using 1M potassium chloride (KCl) extraction. NO_3^- concentration was determined by the cadmium reduction method, while NH_4^+ concentration was determined by the colorimetric reaction. Analysis of variance (ANOVA) and Fisher's least significant difference (LSD) pairwise comparisons at $\alpha < 0.05$ was performed using the R-4.1.2 software.

RESULTS AND DISCUSSION

Soil nitrate (NO_3^-) changes

At the beginning of the corn growth stage, there was no difference in the content of NO_3^- between the N rates, neither with the use of the NI **(Figure 1A & 1B)**. There was only a significant difference due to the application of N to the soil. By the V4 growth stage, there was an increase in the amount of NO_3^- at the 0-12 in depth for the highest rates of 150 and 200 lbs N acre^{-1}, however, there was no effect of the inhibitor at this stage **(Figure 1A)**. In the same depth (0-12 in) at V6 stage, a peak was reached and directly proportional to the increment of applied N rates **(Figure 3)**. Even though the concentration was lower and decreased, at V8, the same relationship was observed for NO_3^- **(Figure 4)**. In V8, an increase in NO_3^- content in the 12-24 in depth corresponded with a decrease at the 0-12 in depth, suggesting a leaching process. This time also corresponds with the time of the highest average of precipitation. When the crop reached the reproductive stages, the NO_3^- present in the soil decreased quickly.

Soil ammonium (NH_4^+) changes

The soil NH_4^+ content was generally higher at the beginning of the season, but with no significant differences due to fertilizer rates or the use of inhibitors **(Figure 2A & 2B)**. At the V6 growth stage there was an increase in soil NH_4^+ content with the higher amount of N applied (200 lbs N acre^{-1}); this increase occurred in both depths and the trend continued to V8 in the 0-12 depth **(Figure 5)**. After the V8 stage, soil NH_4^+ quickly decreased to background levels until the end of the season.

Results from this study suggest that the increased application of N helps increase mineral soil N content. The use of NI shows lower levels of NO_3^- early in the season, likely due to the reduction in the rate of the nitrification process.

REFERENCES

Cameron, K.C., Di, H.J., and Moir, J.L. 2013. Nitrogen losses from the soil/plant system: A review. Ann. Appl. Biol. 162:145–173. https://doi.org/10.1016/j.still.2017.12.023

Corrochano-Monsalve, M., González-Murua, C., Bozal-Leorri, A., Lezama, L., and Artetxe, B. 2021. Mechanism of action of nitrification inhibitors based on dimethylpyrazole: A matter of chelation. Science of The Total Environment, 752: 141885 https://doi.org/10.1016/j.scitotenv.2020.141885

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

Sites	County	Soil	Texture	Planting Date	0-6 in		0-24 in	
					pH	OM	NO_3^-	NH_4^+
						%	lbs acre^{-1}	
1	Riley	Smolan	Silt Loam	4/24/17	7.3	1.8	16.4	42
2	Republic	Hastings	Silty Clay Loam	4/25/17	5.8	3.3	23.6	38.8
3	Riley	Smolan	Silt Loam	4/28/18	8.0	1.9	10.4	0
4	Shawnee	Eudora	Silt Loam	5/07/18	6.9	1.4	105.2	44
5	Riley	Smolan	Silt Loam	05/25/19	5.7	1.6	22.8	16.8
6	Shawnee	Eudora	Silt Loam	04/25/19	6.6	1.5	61.6	16.8
7	Riley	Belvue	Silt Loam	04/30/20	6.5	2.2	7.6	14
8	Shawnee	Eudora	Silt Loam	04/23/20	6.4	1.3	15.2	14.8

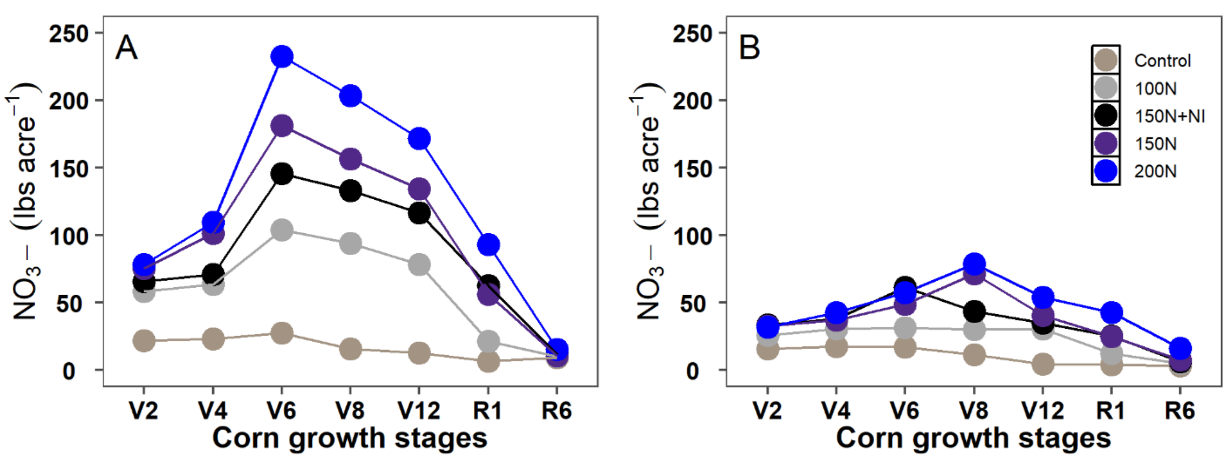

Figure 1. Average soil nitrate (NO_3^-) content throughout the corn growing season as affected by nitrogen fertilizer rates and nitrification inhibitor. **(A)** Soil nitrate (NO_3^-) content at the 0-12 in depth. **(B)** Soil nitrate (NO_3^-) content at the 12-24 in depth.

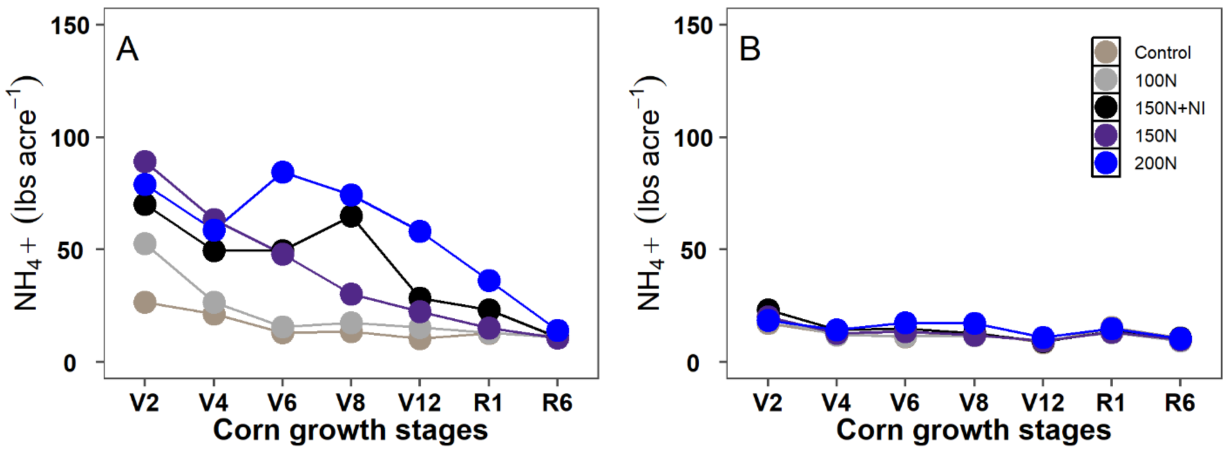

Figure 2. Average soil ammonium (NH_4^+) content throughout the corn growing season as affected by nitrogen fertilizer rates and nitrification inhibitor. **(A)** Soil ammonium (NH_4^+) content at the 0-12 in depth. **(B)** Soil ammonium (NH_4^+) content at the 12-24 in depth.

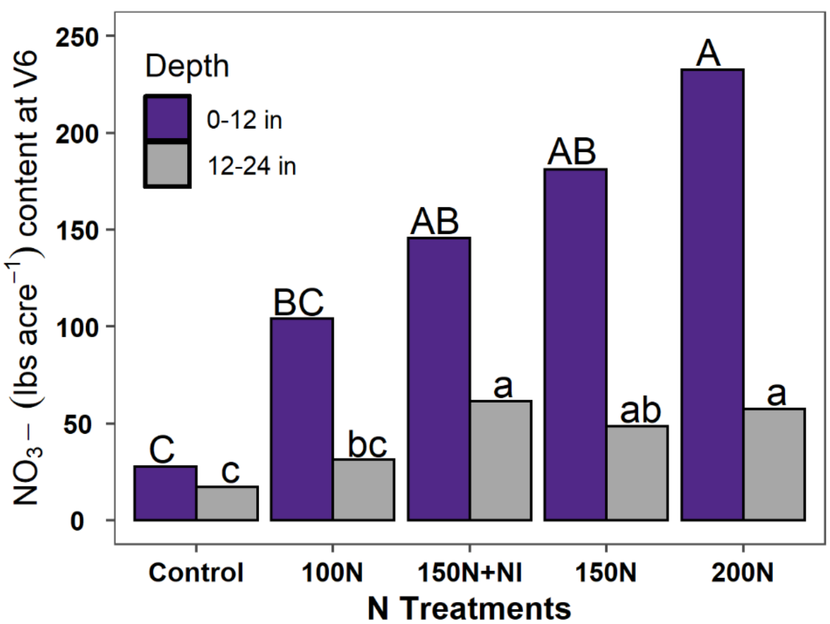

Figure 3. Average soil nitrate (NO_3^-) content throughout the V6 corn growth stage as affected by nitrogen fertilizer rates and nitrification inhibitor. Uppercase letters are used to compare NO_3^- content in the soil at 0-12 in depth ($P < 0.05$). Lowercase letters are used to compare NO_3^- content in the soil at 12-24 in depth ($P < 0.05$).

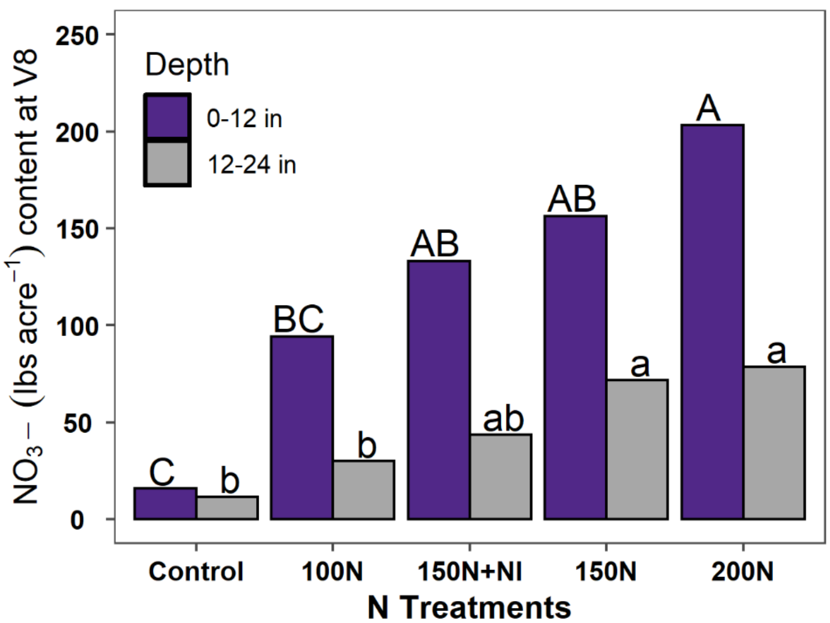

Figure 4. Average soil nitrate (NO_3^-) content throughout the V8 corn growth stage as affected by nitrogen fertilizer rates and nitrification inhibitor. Uppercase letters are used to compare NO_3^- content in the soil at 0-12 in depth ($P < 0.05$). Lowercase letters are used to compare NO_3^- content in the soil at 12-24 in depth ($P < 0.05$).

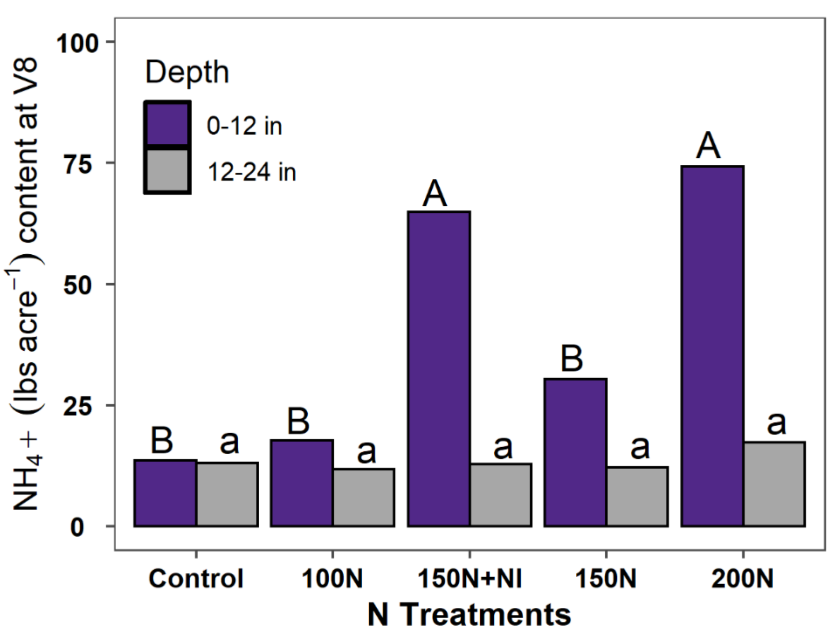

Figure 5. Average soil ammonium (NH_4^+) content throughout the V8 corn growth stage as affected by nitrogen fertilizer rates and nitrification inhibitor. Uppercase letters are used to compare NH_4^+ content in the soil at 0-12 in depth ($P < 0.05$). Lowercase letters are used to compare NH_4^+ content in the soil at 12-24 in depth ($P < 0.05$).