Assessing Nitrogen Use Efficiency and Nitrate Leaching of Maize Grown on Irrigated Sandy Soils

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Introduction

- Irrigated sands are some of the most productive and environmentally sensitive areas in Minnesota.
- Reducing nitrate nitrogen (NO_3-N) leaching is critical for corn (*Zea mays* L.*)* production as ground water is a major source of drinking water in these soils. At the same time, substantial amount of nitrogen (N) is required to maximize corn yield.
- Time and rate of application and source of N are important variables that can be managed to decrease NO_3-N losses while maintaining or improving grain yields. However, these variables need to be further investigated to assess their potential to meet yield and water quality goals.

Objectives

- The objective of this study was to evaluate agricultural technologies that may improve nitrogen (N) management for profitable corn production and mitigate negative effects of NO_3-N in groundwater.

Materials and Methods

- Two locations: **Dakota County**, MN with continuous corn (C-C) on a Sparta loamy fine sand (sandy, mixed, mesic, Entic Hapludolls) and **Pope County**, MN with corn after soybeans (C-S), soybean after corn (S-C) and C-C on an Estherville Loam (sandy, mixed, mesic, Typic Hapludolls).
- Urea (46-0-0) broadcast at rates of 0, 45, 90, 135, 180, 225, 270, and 315 kg N ha^{-1} as a split applications, half of the rate at pre-plant and half at V4 development stage. Four additional treatments were applied at pre-plant: 180 and 225 kg N ha^{-1} as polymer-coated urea (ESN) (44-0-0), 180 kg N ha^{-1} as SuperU (46-0-0), and a blend of 90 kg N ha^{-1} as urea and 90 kg N ha^{-1} as ESN.
- Treatments were applied by hand in 4.6 x 12.2 m six-row plots (0.76 m row spacing) in a randomized complete block design with four replications.
- Whole plant samples were taken at V8, V12, and R6 development stage to determine dry biomass and N content.
- Crop canopy was sensed at the V8 and V12 development stage.
- Grain yield was obtained during fall harvest.
- Weekly NO_3-N leachate samples were taken with suction cup lysimeters at each site from the control, 135-270 kg N ha^{-1} as urea, and the SuperU, ESN, and ESN/urea blend each at 180 kg N ha^{-1}.
- Each plot with lysimeters contained three lysimeters. In Pope Co. six passive capillary lysimeters were also installed to quantify the amount of water moving below the root zone.
- Post-harvest soil samples were taken for N content in 30 cm increments to 60 cm in Pope Co. and 120 cm in Dakota Co.

Results

Yield

- While these irrigated sands can be highly productive, they required a high amount of N. The Maximum Return to N (MTRN) rate calculated at 0.1 N to corn price ratio and grain yield at the MRTN is shown in Table 1.

Table 1: Maximum Return to Nitrogen in yield and N rate, at a 0.1 N to corn price ratio.

Location	Yield (Mg ha^{-1})	N Rate (kg N ha^{-1})
Dakota	13.5	243
Pope (C-C)	12.8	278
Pope (C-S)	13.0	264

- While the crop was very responsive to N (Table 1), the source of N was not as important. There was no benefit to using ESN, ESN/urea blends, or SuperU at pre-plant relative to the Univ. of Minnesota's best management practice (BMP) of split urea application.

Canopy Sensing

- Several crop sensing technologies varied in their capacity to positively correlate to grain yield at V8 and V12 development stage with SPAD providing the greatest correlation (Table 2).

Table 2: Correlation value (R^2) to grain yield based on several crop sensing technologies at V8 and V12 development stage

Technology	Development Stage	
	V8	V12
SPAD meter	0.68	0.89
Crop Circle (NDVI)	0.59	0.49
Green Seeker (NDVI)	0.59	No corr.

Soil-Water Nitrate

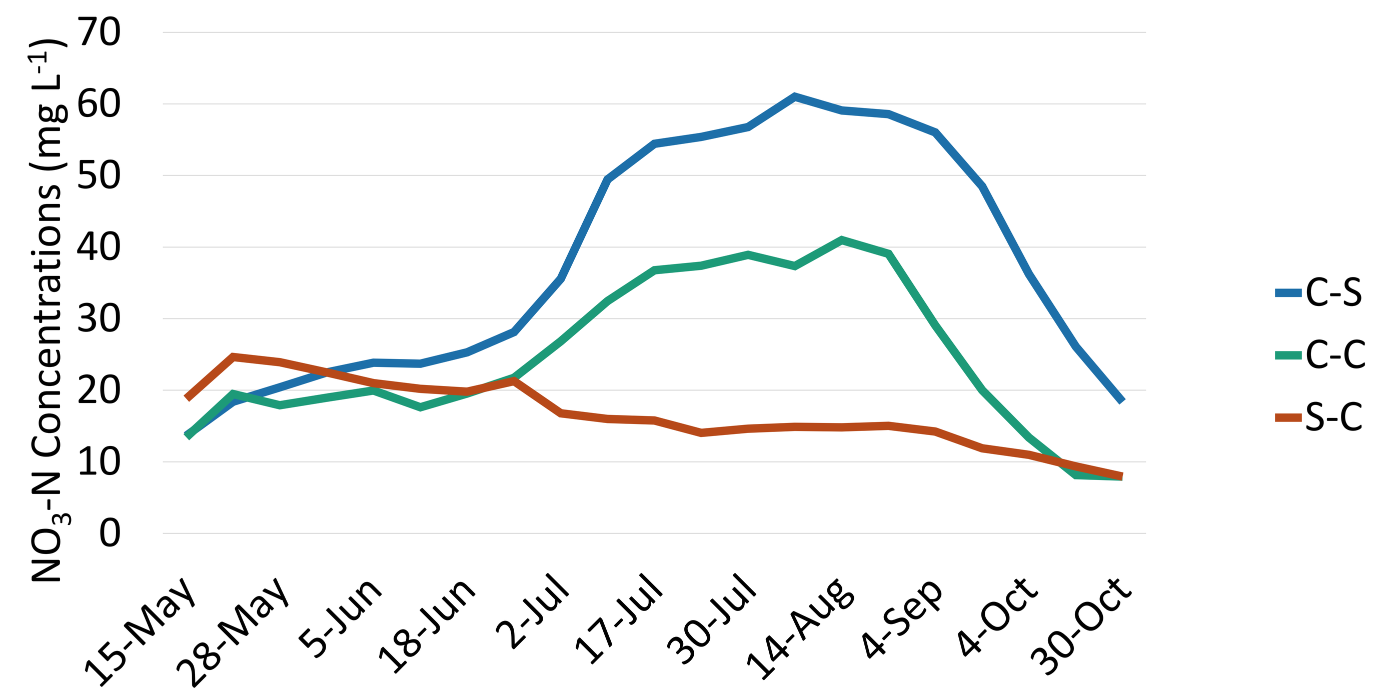
- In Dakota Co. the season-long mean water NO_3-N concentration increased from 6.6 (in the unfertilized check) to 15.4 mg L^{-1} in the 135 kg N ha^{-1} rate but no difference in NO_3-N concentrations were observed between the 135 and 270 kg N ha^{-1} rates (range 13.8 to 15.4 mg L^{-1}) (Data not shown).
- Similar results were observed in Pope Co. where averaged across cropping systems NO_3-N was lower (16.1 mg L^{-1}) in the unfertilized check than the 180 kg N ha^{-1} rate (26.5 mg L^{-1}) but no difference in NO_3-N concentrations were observed between the 135 and 270 kg N ha^{-1} rates (range 22.2 to 27.7 mg L^{-1}) (Data not shown).

Table3: Effect of sources of nitrogen (at 180 kg ha^{-1}) on leachate NO_3-N concentration in Dakota Co. and concentration and load for Pope Co.

Source	Dakota Co.	Pope Co.	
	mg NO_3-N L^{-1}	mg NO_3-N L^{-1}	kg NO_3-N ha^{-1}
Urea	15.45 b	21.9 a	30.1 a
ESN	14.03 b	29.2 a	39.2 a
ESN/Urea	20.04 a	29.3 a	42.0 a
SuperU	20.92 ab	30.3 a	36.2 a

- As with yield, there was no difference between N source in leachate NO_3-N concentrations and load in Pope Co. Similar results were observed in Dakota Co., though concentrations showed no consistent pattern (Table 3).
- In Pope Co. corn in the C-S rotation leached approximately 37% more (36.7 mg L^{-1}) than corn in the C-C rotation that had an average NO_3-N concentration of 23.8 mg L^{-1} (Fig. 1).
- There was no residual N from the previous corn crop as no difference in water NO_3-N concentrations due to previous N rate in corn was detected in the S-C rotation. The season-long average was 16.6 mg NO_3-L^{-1} (Fig. 1).

Figure 1: NO_3-N Leachate in Pope Co. in corn-soybean (C-S), continuous corn (C-C) and soybean-corn (S-C) in 2013.



Soil Nitrate

- In Pope Co. end of season soil NO_3-N from the control to the 315 kg N ha^{-1} rate ranged from 1.4 to 5.0 mg kg^{-1} in C-C and from 2.1 to 3.1 mg kg^{-1} in C-S but the increase was not consistent with N rates (Data not shown). Similar results were observed in Dakota Co.

Preliminary Conclusion

- Reducing N rate from the MRTN would not cause a significant reduction in NO_3-N leaching but would reduce grain yield substantially.
- With regards to improved grain yield and reduced NO_3-N leaching, split pre-plant/sidedress application of urea remains a BMP relative to other management strategies tested.

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